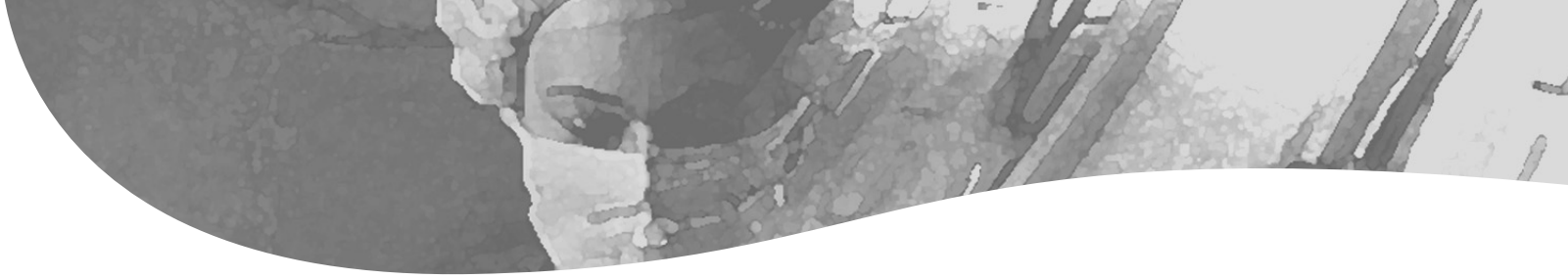

Valleylab™

Service Manual

LigaSure™ Vessel Sealing Generator

This manual and the equipment it describes are for use only by qualified medical professionals trained in the particular technique and surgical procedure to be performed. It is intended as a guide for servicing the Valleylab LigaSure™ Vessel Sealing Generator only. Additional information about using the generator is available in the ***LigaSure™ Vessel Sealing Generator User's Guide***.

Caution

Federal (USA) law restricts this device to sale by or on the order of a physician.

Equipment covered in this manual
Valleylab LigaSure™ vessel sealing generator - 120V / 240 V

The ***LigaSure™ Vessel Sealing Generator Service Manual*** consists of two parts—the text and a Schematics Supplement.

Valleylab Part Number 1023798
Effective Date August 2009

Trademark acknowledgments
LigaSure™ and Instant Response™ are trademarks of Valleylab, Boulder, CO.

Patents

One or more of the following U.S. patents and corresponding foreign patents cover the LigaSure vessel sealing generator and accessories:

5,776,130	6,228,083	6,682,528
5,599,344	6,277,117	6,685,701
5,720,744	6,398,779	6,726,686
5,827,271	6,402,743	6,743,229
6,033,399	6,451,018	D-424,694
6,039,733	6,464,704	D-425,201
6,050,996	6,458,130	D-449,886
6,068,627	6,511,480	D-457,958
6,179,834	6,585,735	D-457,959

Additional patents pending.

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Preface

The service manual describes the Valleylab LigaSure vessel sealing generator:

- Descriptions of the system, its functions, specifications, and theory of operation
- Step-by-step instructions on how to set up, calibrate, troubleshoot, and maintain the system
- Step-by-step instructions on how to replace specific components
- Parts lists and schematics.

Conventions Used in this Guide

Warning

Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

Caution

Indicates a hazardous situation which, if not avoided, may result in minor or moderate injury.

Notice

Indicates a hazard which may result in product damage.

Important

Indicates an operating tip or maintenance suggestion.

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CHAPTER 1

Service Personnel Safety

Valleylab stresses safety in the use and servicing of its electrosurgical equipment. This chapter presents the following:

- Safety information
- Warnings, Cautions, and Notices

Refer to the Preface, *Conventions Used In This Guide*, for further information on Warnings, Cautions, and Notices.

Safety Information

The safe and effective servicing of electrosurgical equipment depends to a large degree on factors solely under the control of the service person. There is no substitute for a properly trained and vigilant service staff.

Warnings, Cautions, and Notices

Before servicing the generator, it is important that you read, understand, and follow the instructions supplied with it and with any other equipment used to install, test, adjust, or repair the generator.

General

Warning

Use the generator only if the self-test has been completed as described. Otherwise, inaccurate power outputs may result.

The instrument receptacles on this generator incorporate a smart interface. They operate with Valleylab LigaSure handsets or smart connector adapters exhibiting smart codes.

Caution

Do not stack equipment on top of the generator or place the generator on top of electrical equipment. These configurations are unstable and/or do not allow for adequate cooling.

Provide as much distance as possible between the electrosurgical generator and other electronic equipment (such as monitors). An activated electrosurgical generator may cause interference with them.

Do not turn the activation tone down to an inaudible level. The activation tone alerts the surgical team when an accessory is active.

Notice

If required by local codes, connect the generator to the hospital equalization connector with an equipotential cable.

Connect the power cord to a wall receptacle having the correct voltage. Otherwise, product damage may result.

Active Accessories

Warning

Electric Shock Hazard Do not connect wet accessories to the generator.

Electric Shock Hazard Ensure that all accessories and adapters are correctly connected and that no metal is exposed.

Caution

Connect accessories to the proper receptacle type. In particular, connect bipolar accessories to the bipolar instrument receptacle only. Connect vessel sealing accessories to the LigaSure seal receptacle only.

Notice

Do not activate the generator until the forceps have made contact with the patient. Product damage may occur.

Fire/Explosion Hazards

Warning

Danger: Explosion Hazard Do not use the generator in the presence of flammable anesthetics, gases, liquids, or objects.

Fire Hazard Do not place active accessories near or in contact with flammable materials (such as gauze or surgical drapes). Electrosurgical accessories that are activated or hot from use can cause a fire. Use a holster to hold electrosurgical accessories safely away from personnel and flammable materials.

Fire Hazard Do not use extension cords.

Fire Hazard For continued protection against fire hazard, replace fuses only with fuses of the same type and rating as the original fuse.

Electric Shock Hazards

Warning

Connect the generator power cord to a properly grounded receptacle. Do not use power plug adapters.

Do not connect a wet power cord to the generator or to the wall receptacle.

Disconnect the power cord before servicing the generator. To allow stored energy to dissipate after power is disconnected, wait at least five minutes before replacing parts.

Always turn off and unplug the generator before cleaning.

Do not touch any exposed wiring or conductive surfaces while the generator is disassembled and energized. Never wear a grounding strap when working on an energized generator.

Warning

When taking measurements or troubleshooting the generator, take appropriate precautions, such as using isolated tools and equipment, using the “one hand rule,’ etc.

Potentially lethal AC and DC voltages are present in the AC line circuitry, high voltage DC circuitry, and associated mounting and heat sink hardware described in this manual. They are not isolated from the AC line. Take appropriate precautions when testing and troubleshooting this area of the generator.

High frequency, high voltage signals that can cause severe burns are present in the RF output stage described in this manual. Take appropriate precautions when testing and troubleshooting this area of the generator.

Servicing

Caution

Read all warnings, cautions, and instructions provided with the Valleylab LigaSure electrosurgical generator before servicing.

The generator contains electrostatic-sensitive components. When repairing the generator, work at a static-control workstation. Wear a grounding strap when handling electrostatic-sensitive components, except when working on an energized generator. Handle circuit boards by their nonconductive edges. Use an antistatic container for transport of electrostatic-sensitive components and circuit boards.

Calibration

Caution

To avoid inadvertent coupling and/or shunting of RF currents around the resistor elements, keep the resistors at least four inches (10.2 cm) away from any metal surface including tabletops and other resistors. This is especially true if several resistors are connected in series or parallel to obtain a specified value. Do not allow the resistor bodies to touch each other.

Notice

After calibration, the generator will be ready to use only after you initiate the internal self-test by turning the generator off, then on.

Calibrate the generator after you install a new battery. Calibration values are lost when the battery is replaced.

Calibrate the generator after you install a new control board.

Calibrate the generator after you service, repair, or install new components, or after you replace any generator board assembly.

Cleaning

Notice

Do not clean the generator with abrasive cleaning or disinfectant compounds, solvents, or other materials that could scratch the panels or damage the generator.

CHAPTER 2

Introduction

This chapter introduces the system features:

- General description
- Vessel sealing
- Bipolar operation
- Instant Response technology

General Description

The LigaSure vessel sealing system is an isolated output electrosurgical generator that provides power for vessel sealing and bipolar surgery.

It includes the following features:

- LigaSure vessel sealing technology
- Vessel sealing regrasp indicator alerts you to situations where a full seal cycle has not been achieved
- Bipolar and macrobipolar modes
- Instant Response technology
- Memory button to recall the most recently used intensity and power settings
- Smart interface for connecting a Valleylab LigaSure handset or smart connector adapter
- Adjustable volume for the activation tone
- Handswitch or footswitch activation
- RF activation port, RS-232 serial port, and expansion port

Vessel Sealing

The LigaSure vessel sealing system provides precise energy delivery and electrode pressure to vessels for a controlled time period to achieve a complete and permanent fusion of the vessel lumen. This system works on isolated arteries and veins up to and including 7 mm in diameter and tissue bundles. The system has been optimized to produce minimal sticking, charring, or thermal spread to adjacent tissue.

Bipolar Operation

Two modes are available:

- Bipolar – for most applications. The system provides low voltage to prevent sparking. The power remains constant over a specific range of tissue impedance, allowing a consistent tissue effect.
- Macrobipolar – for bipolar cutting or rapid coagulation. The system provides higher voltage and greater power than with the bipolar mode.

Instant Response Technology

The LigaSure generator automatically senses tissue impedance and adjusts the output to maintain a consistent effect across different tissue types. This adjustment is based on the power setting and the level of tissue impedance. The system controls maximum output voltage to reduce tissue damage and to minimize sparking.

CHAPTER 3

Controls, Indicators, and Receptacles

This chapter describes the front and rear panels, including all controls, indicators, and receptacles. It also describes the fuse drawer and all ports.

List of Components

The LigaSure vessel sealing system, a self-contained unit, consists of a main enclosure (cover and base) and power cord. The generator includes the following components:

- Front panel — power switch; regrasp indicator; controls for setting the output power and intensity; a button for recalling the most recently used power and intensity settings; receptacles for connecting electrosurgical accessories; displays for viewing power and intensity control settings; and smart indicators for correct Valleylab LigaSure handset and bipolar adapter use.
- Rear panel — volume control; two footswitch receptacles; option panel (containing RF activation port, RS-232 serial port, and expansion port); equipotential grounding lug; and power entry module (fuse drawer with two fuses and power cord receptacle).
- Internal —control (microcontroller) board; display board; smart board; footswitch board; a high voltage power supply; radio frequency (RF) board; and a low voltage power supply.

Refer to Chapter 5, *Principles of Operation* for details about the interaction of the main components and for circuit board descriptions.

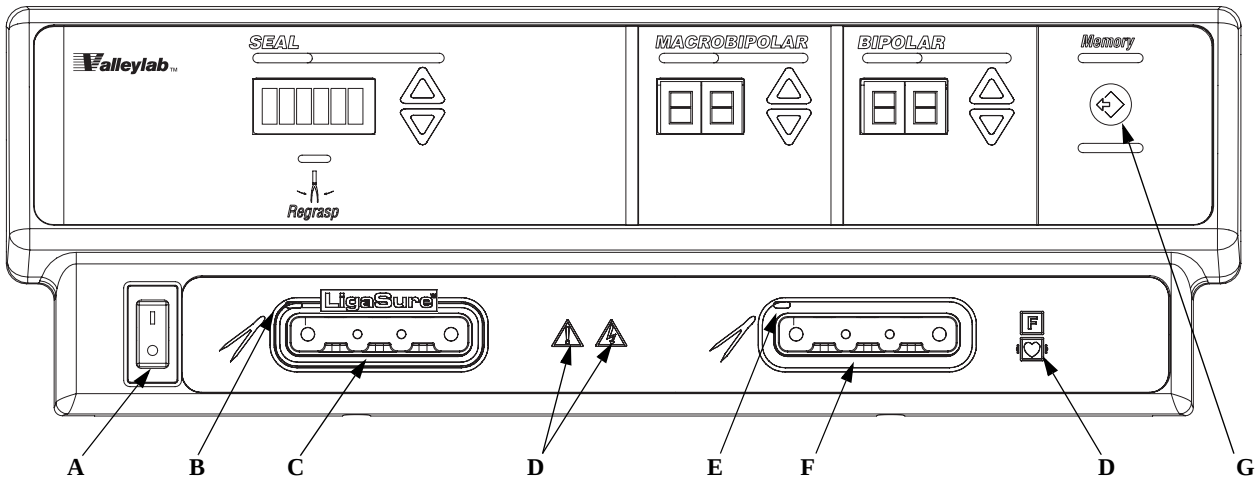
Front Panel

Figure 3-1.
Domestic and international front panels

Domestic

Vessel Sealing Controls and Indicators (page 3-4)

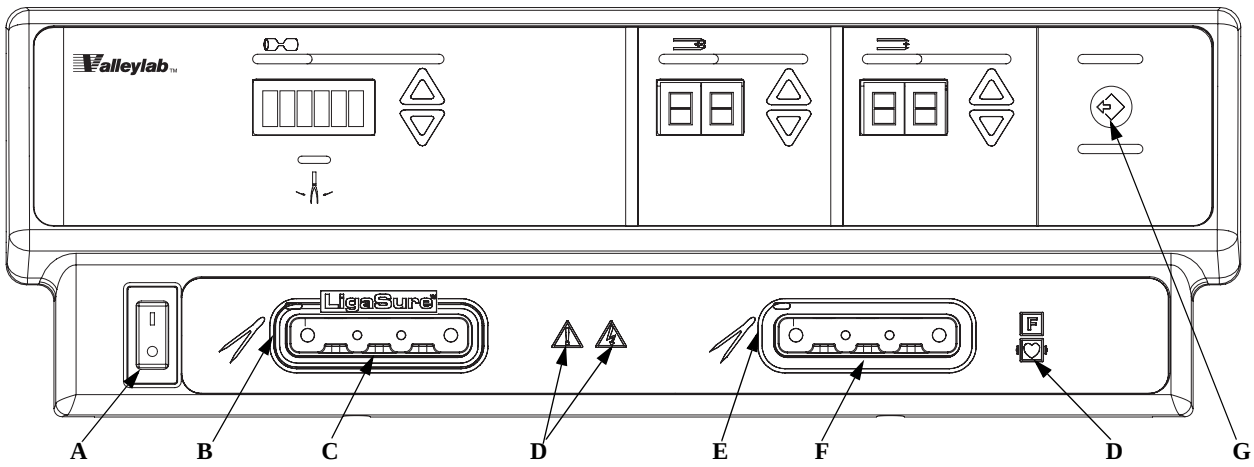
Bipolar Controls and Indicators (page 3-6)



International

Vessel Sealing Controls and Indicators (page 3-4)

Bipolar Controls and Indicators (page 3-6)



Features

These callouts refer to both the domestic and international front panels:

A. Power switch

- To turn on the generator, press (|).
- To turn off the generator, press (O).

B. Vessel sealing receptacle smart indicator

C. Vessel sealing handset receptacle

D. Standard and IEC classifications

E. Bipolar receptacle smart indicator

F. Bipolar handset receptacle

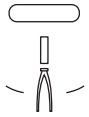
G. Memory button

Pressing this button resets the generator to recall the most recently used intensity and power settings.

For details of the vessel sealing controls and indicators and the bipolar controls and indicators, refer to the following pages in this chapter.

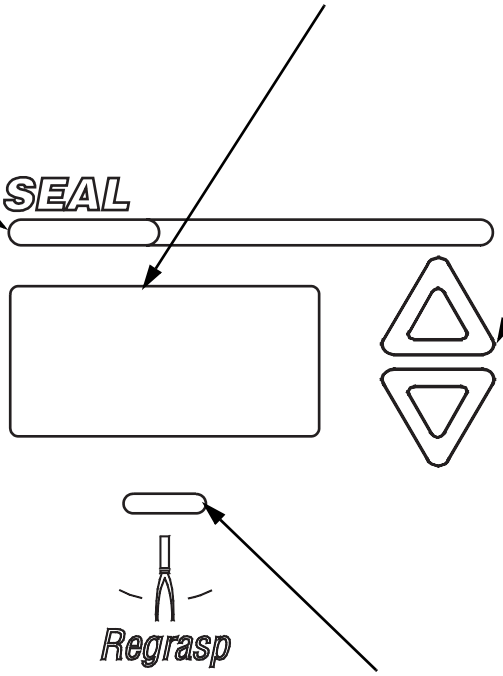
Symbols

Several symbols appear on the international front panel:

Symbol	Indicates
	Vessel Sealing
	Regrasp
	Macrobipolar
	Bipolar
	Memory

Vessel Sealing Controls and Indicators

Figure 3-2.
Vessel sealing intensity control, activation indicator, and regrasp indicator



Vessel Sealing Intensity Display

A bar graph indicates the relative seal intensity setting.

Seal RF Activation Lamp

Illuminates with handswitch or footswitch activation.

Vessel Sealing Intensity Buttons

Press ∆ to increase the intensity.
Press ∇ to decrease the intensity.

Regrasp Indicator

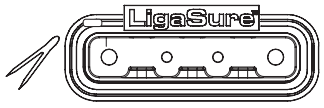
Illuminates if the tissue is not sealed. This may be due to:

- Tissue not responding to RF energy
- Tissue impedance is out of range
- Seal cycle was interrupted before the cycle was complete
- Maximum seal cycle time has been reached

Vessel Sealing Handset Receptacle (purple)

You can only connect a LigaSure vessel sealing instrument to this receptacle.

Figure 3-3.
Vessel sealing handset receptacle (purple)



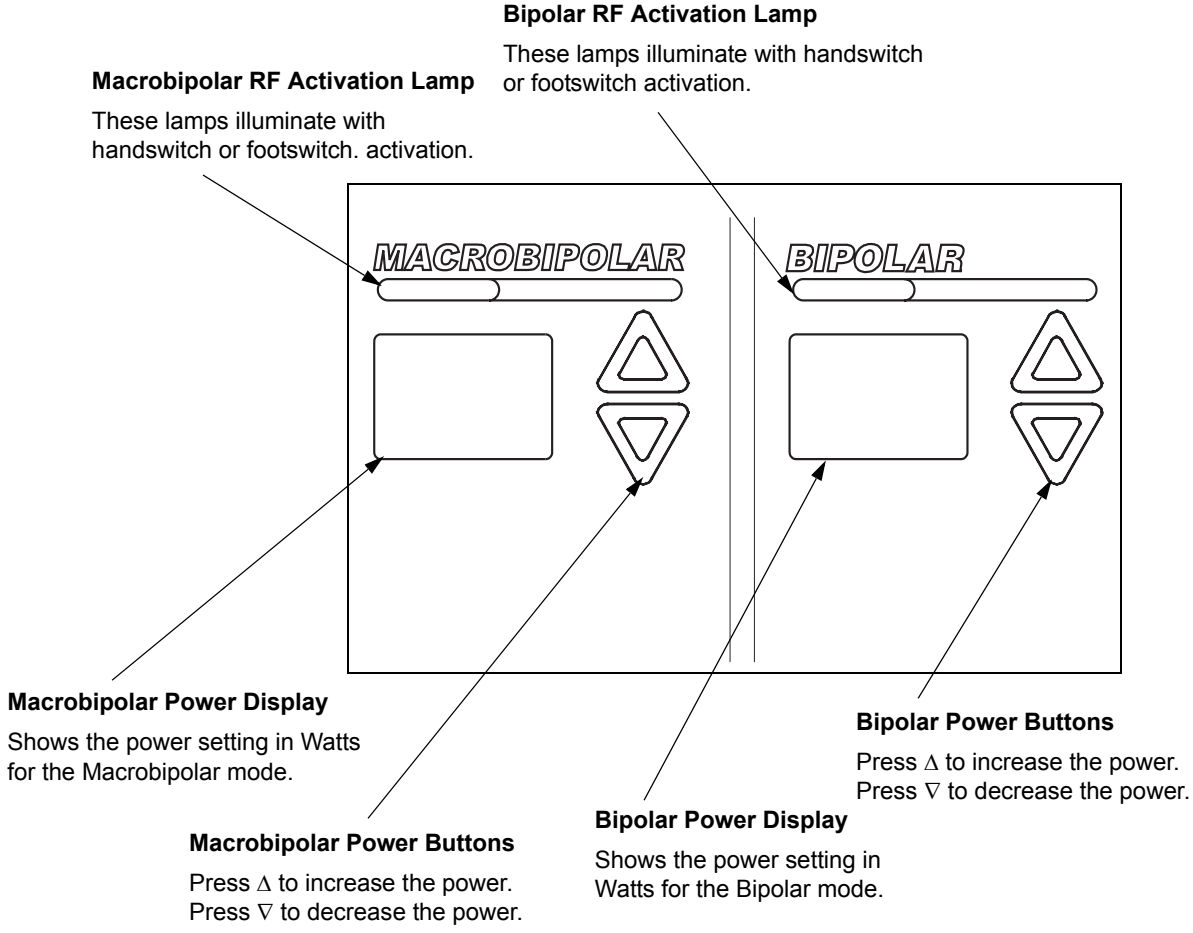
Connect a footswitching instrument with a multi-pin connector.

This receptacle is designed to accept a Valleylab Smart Connector.

When the handset is correctly connected, the vessel sealing receptacle indicator illuminates green.

Bipolar Controls and Indicators

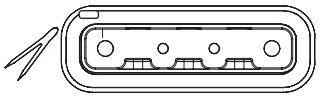
Figure 3-4.
Bipolar controls and indicators


Bipolar RF Activation Lamp
These lamps illuminate with handswitch or footswitch activation.
Macrobipolar RF Activation Lamp
These lamps illuminate with handswitch or footswitch. activation.
MACROBIPOLAR
BIPOLAR
Macrobipolar Power Display
Shows the power setting in Watts for the Macrobipolar mode.
Macrobipolar Power Buttons
Press Δ to increase the power.
Press ∇ to decrease the power.
Bipolar Power Display
Shows the power setting in Watts for the Bipolar mode.
Bipolar Power Buttons
Press Δ to increase the power.
Press ∇ to decrease the power.

Bipolar Handset Receptacle (blue)

You can connect either a footswitching or handswitching bipolar/macrobipolar instrument to this receptacle.

Figure 3-5.
Bipolar handset receptacle (blue)



Connect a footswitching instrument with a two-pin connector.

or

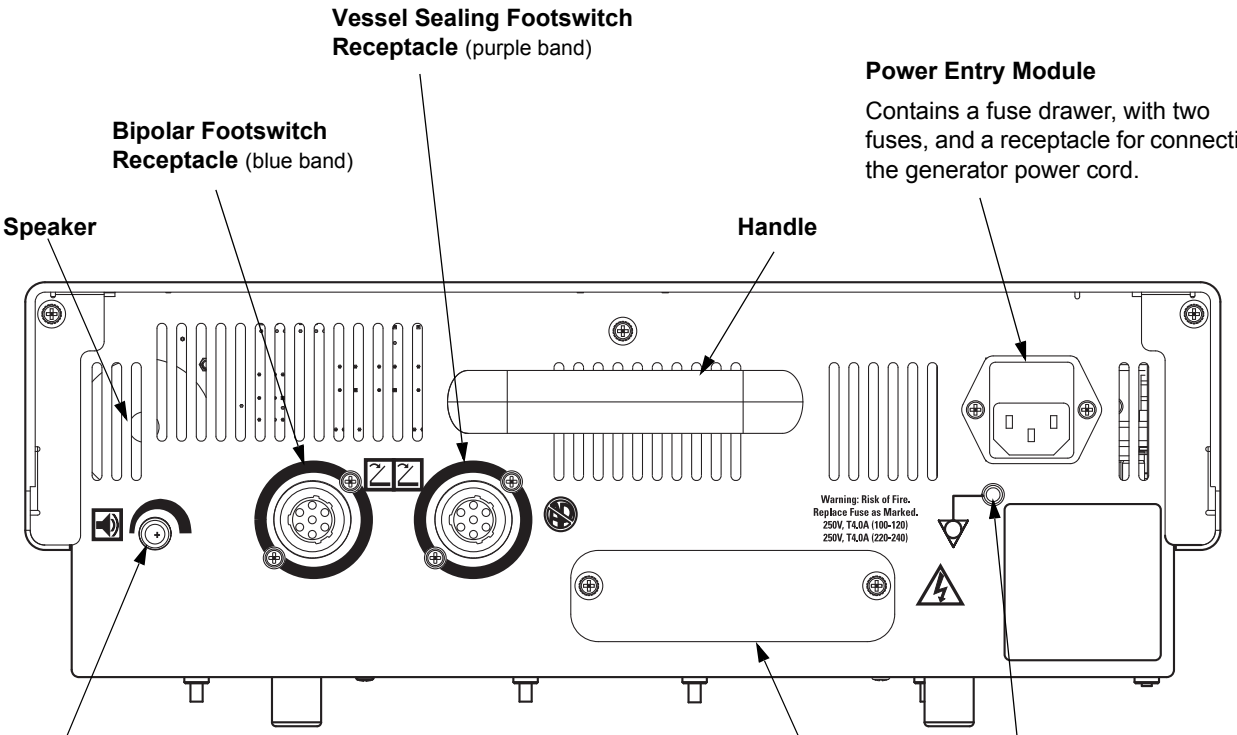
Connect a handswitching instrument with a three-pin connector.

This receptacle is designed to accept a Valleylab Smart Connector or a Valleylab Smart Connector adapter. If the bipolar instrument you select does not have a Smart Connector, you must use the Valleylab Smart Connector adapter (p/n LS0500).

When the bipolar handset or Valleylab Smart Connector is correctly connected, the bipolar receptacle indicator light illuminates green.

Rear Panel

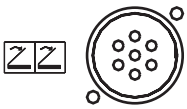
Figure 3-6.
Rear panel controls and receptacles


Vessel Sealing Footswitch Receptacle (purple band)
Power Entry Module
Contains a fuse drawer, with two fuses, and a receptacle for connecting the generator power cord.
Bipolar Footswitch Receptacle (blue band)
Speaker
Handle
Warning: Risk of Fire.
Replace Fuse as Marked.
250V, T4,0A (100-120)
250V, T4,0A (220-240)
Volume Knob
To increase the volume, turn the knob clockwise.
To decrease the volume, turn it counterclockwise.
You cannot deactivate the activation tone or adjust the Regrasp indicator tone volume.
Option Panel
Grounding Lug
Use this to connect the generator to earth ground.

Vessel Sealing Footswitch Receptacle (purple)

Connect either the two-pedal vessel sealing footswitch or the single-pedal vessel sealing footswitch to this receptacle.

Figure 3-7.
Vessel sealing footswitch receptacle (purple)



Two Pedal Footswitch

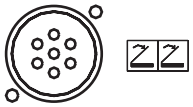
The connected footswitch activates ***either*** vessel sealing or bipolar output for the LigaSure instrument that is connected to the Vessel Sealing Handset receptacle on the front panel.

Single Pedal Footswitch

The connected footswitch activates ***only*** the vessel sealing output for the LigaSure instrument that is connected to the Vessel Sealing Handset receptacle on the front panel

Bipolar Footswitch Receptacle (blue)

Figure 3-8.
Bipolar footswitch receptacle (blue)



Connect the bipolar/macrobipolar footswitch when you connect a bipolar footswitching instrument to the generator.

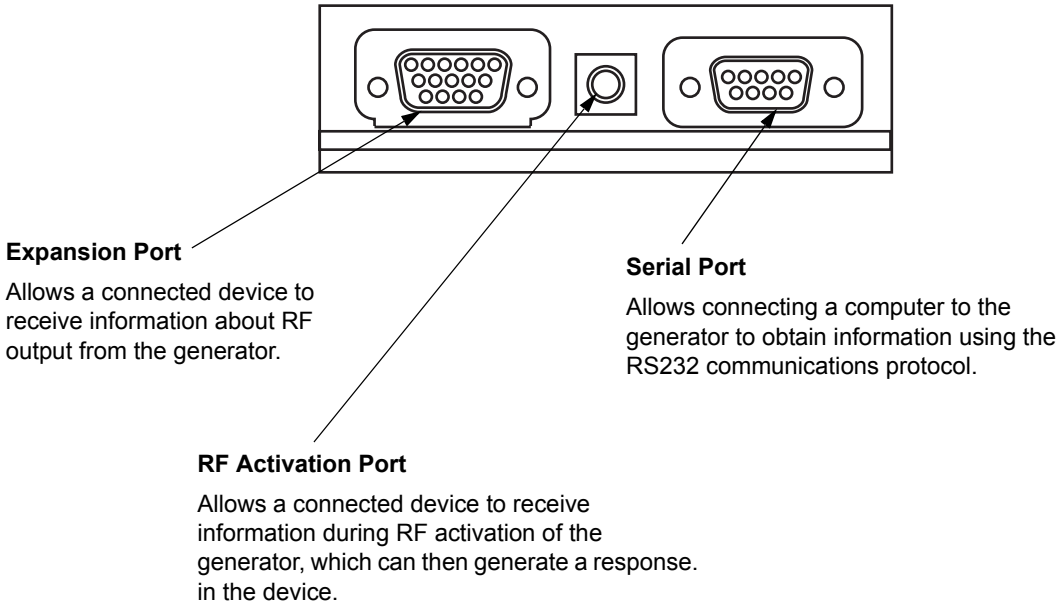
Connect the two-pedal bipolar footswitch to this receptacle.

The connected footswitch activates bipolar or macrobipolar output for the bipolar instrument that is connected to the Bipolar handset receptacle on the front panel.

Option Panel

A removable plate on the rear panel covers a serial port, an RF (radio frequency) activation port, and an expansion port. To review the technical specifications for each port, refer to Chapter 4, *Technical Specifications*.

Figure 3-9.
The option panel


Expansion Port
Allows a connected device to receive information about RF output from the generator.
Serial Port
Allows connecting a computer to the generator to obtain information using the RS232 communications protocol.
RF Activation Port
Allows a connected device to receive information during RF activation of the generator, which can then generate a response. in the device.

CHAPTER 4

Technical Specifications

All specifications are nominal and subject to change without notice. A specification referred to as “typical” is within ± 20% of a stated value at room temperature (25° C / 77° F) and a nominal input power voltage.

Performance Characteristics

General

Output configuration	Isolated output
Cooling	Natural convection
Display	Two (2) digital seven-segment displays: 1.9 cm (0.75 in.) each Six (6) bar graph displays: 1.0 cm (0.4 in.) each
Mounting	A Valleylab cart (UC8009) or a stable flat surface

Dimensions and Weight

Width	38.6 cm (15.2 in.)
Depth	40.6 cm (16.0 in.)
Height	12.7 cm (5.0 in.) not including feet
Weight	5.9 kg (13 lbs)

Operating Parameters

Ambient temperature range	10° to 40° C (50° to 104° F)
Relative humidity	15% to 90%, noncondensing
Atmospheric pressure	700 to 1060 millibars
Warm-up time	If transported or stored at temperatures outside the operating temperature range, allow one hour for the generator to reach room temperature before using.

Transport and Storage

Ambient temperature range	– 34° to 70° C (– 29° to 158° F)
Relative humidity	0% to 95%, noncondensing
Atmospheric pressure	500 to 1060 millibars
Duration of storage	If you stored the generator over one year, check the battery to measure the Vdc minimum and complete a full checkout (including calibration) before use. Contact Valleylab Service for information.

Duty Cycle

Under maximum output settings and rated load conditions (100 ohm load) the generator is suitable for activation times of 10 seconds on, 30 seconds off, for one hour.

Internal Memory

Memory type	Nonvolatile, battery-backed RAM
Battery type	3 V lithium button cell
Battery life	5 years

Audio Volume

The stated audio levels are at a distance of one meter. Alarm tones meet the requirements of IEC 60601-2-2.

Activation Tone

Volume (adjustable)	45 dBA minimum
Frequency (nominal)	Seal Mode - 440 Hz Macrobipolar Mode - 520 Hz Bipolar Mode - 660 Hz
Duration	Continuous while the generator is activated.

Seal Complete Tone

Volume (not adjustable)	65 dBA minimum
Frequency	440 Hz
Duration	Two short beeps when vessel sealing cycle is complete

Regrasp Tone

Volume (not adjustable)	65 dBA minimum
Frequency	780 Hz
Duration	Four pulsed tones

Alarm Tone

Volume (not adjustable)	65 dBA minimum
Frequency	985 Hz - 780 Hz; 985 Hz nominal

Serial Port

RS-232 compatible; 9600 baud, 8 data bits, 1 stop bit, no parity

A 9-pin connector supporting the following signals:

- pin 2 – isolated transmit (serial data output transmit line)
- pin 3 – isolated receive (serial data input receive line)
- pin 5 – isolated ground (reference for transmit and receive)

RF Activation Port

The RF activation port is a subminiature phone jack attached to the contacts of a small relay. The contacts close when you activate the generator, but remain open at all other times. This port provides a means to tell other equipment that the generator is producing RF. This may be useful when making EEG or ECG measurements.

Expansion Port

This 15-pin connector supports the following signals:

- pin 2 – isolated transmit (serial data output transmit line)
- pin 3 – isolated receive (serial data input receive line)
- pin 5 – isolated ground (reference for transmit and receive)
- pin 7 – regrasp indicator (active high)
- pin 8 – RF_ACT indicator (active high when RF is active)
- pin 9 – RF disable: input signal that, when activated by an external device, disables active RF output
- pin 10 – RF current: output signal proportional to active RF current at 0.8 amp/volt
- pin 11 – RF voltage: output signal proportional to active RF voltage at 205 Vrms/volt

Expansion power (from the low voltage power supply):

+ 5 V (pin 6), – 12 V (pin 14), + 12 V (pin 15), and ground (pins 12 & 13)

Rated fuse current:

1 Amp, Slo Blo, @ +5 Vac
0.25 Amp, Slo Blo, @ ±12 Vac

Low Frequency (50-60 Hz) Leakage Current (AAMI HF-18-1993)

Enclosure source current, ground open	< 300 µA
Source current, patient leads, all outputs:	
Normal polarity, intact ground	< 10 µA
Normal polarity, ground open	< 50 µA
Reverse polarity, ground open	< 50 µA
Sink current at high line, all inputs	< 10 µA @ 120 V < 50 µA @ 264 V

High Frequency (RF) Leakage Current (IEC 60601-2-2)

Bipolar RF leakage current	≤ 69 mA rms

Input Power

120 Volt	240 Volt
Maximum power at nominal line voltage	Maximum power at nominal line voltage
Idle: 35 VA	Idle: 35 VA
Bipolar: 360 VA	Bipolar: 360 VA
Seal: 480 VA	Seal: 480 VA
Full regulation range	Full regulation range
90 to 135 Vac	186 to 264 Vac
Operating range	Operating range
85 to 140 Vac	170 to 264 Vac
Mains current maximum	Mains current maximum
Idle: 300 mA_{rms}	Idle: 300 mA_{rms}
Bipolar: 3.0 A_{rms}	Bipolar: 1.5 A_{rms}
Seal: 4.0 A_{rms}	Seal: 2.0 A_{rms}
Mains line frequency range (nominal)	Mains line frequency range (nominal)
50 to 60 Hz	50 to 60 Hz
Fuses (2) 4 A, 250 V, 3 AG, SLO-BLO	Fuses (2) 4 A, 250 V, 3 AG, SLO-BLO[1]
Power plug	Power plug
3-prong hospital grade connector	3-prong locally approved connector

1. The nominal operating power of the LigaSure generator is 480 VA for a maximum operating current of 2.0 A. However, because the unit is fused for 4.0 A, the worst-case power would be 960 VA (due to input voltages of 220–240 Volts), as indicated by the labeling on the rear panel of the generator.

Power Cord Specification

This unit was equipped from the factory with either a 110VAC hospital grade NEMA 5-15 power cord or a 220VAC CEE7/7 power cord. Should the AC power cord need to be replaced to match another plug configuration, the replacement plug/cable/receptacle configuration must meet or exceed the following specifications:

100-120 VAC

Cable - SJT16/3, IEC color code, maximum length 15 ft (5 m)
Plug - minimum 10 A - 125 VAC
Unit receptacle - IEC female, minimum 10 A - 125 VAC

220-240 VAC

Cable - H05VVF3G1.0 VDE, maximum length 15’ (5 meters)
Plug - minimum 6 A - 250VAC
Unit receptacle - IEC female, minimum 6 A - 250VAC

Standards and IEC Classifications

The LigaSure Generator meets all pertinent clauses of IEC 60601-1 second edition and IEC 60601-2-2 third edition.

ATTENTION
Consult accompanying documents.

The generator output is floating (isolated) with respect to ground.

DANGER
Explosion risk if used with flammable anesthetics.

To reduce the risk of electric shock, do not remove the cover. Refer servicing to qualified service personnel.

Non-Ionizing Radiation

Classified with respect to electrical shock, fire, and mechanical hazards only in accordance with UL60601-1 and CAN/CSA C22.2 No. 601.1.

Class I Equipment (IEC 60601-1)

Accessible conductive parts cannot become live in the event of a basic insulation failure because of the way in which they connect to the protective earth conductor.

Type CF Equipment (IEC 60601-1)/Defibrillator Proof

This generator provides a high degree of protection against electric shock, particularly regarding allowable leakage currents. It is type CF isolated (floating) output and poses no fibrillation danger.

This generator complies with the ANSI/AAMI HF18 specifications for “defibrillator proof” designation and IEC 60601-2-2.

Liquid Spillage (IEC 60601-2-2, clause 44.3)

This generator enclosure is constructed so that liquid spillage in normal use does not wet electrical insulation or other components which, when wet, are likely to affect adversely the safety of the generator.

Static Electricity Discharge Interference (IEC 60601-1-2 and IEC 61000-4-2)

This generator enclosure can withstand an 8 kV electrostatic air discharge.

Electromagnetic Interference

When placed on or beneath an activated Valleylab electrosurgical generator, this generator operates without interference. The generator minimizes electromagnetic interference to video equipment used in the operating room.

Electromagnetic Compatibility (IEC 60601-1-2 and IEC 60601-2-2)

This generator complies with the appropriate IEC 60601-1-2 and 60601-2-2 specifications regarding electromagnetic compatibility.

Notice
The LigaSure should not be used adjacent to or stacked with equipment other than specified in the LigaSure User Guide and Service Manual. If adjacent or stacked use is necessary, the LigaSure should be observed to verify normal operation in the configuration in which it will be used.
The LigaSure intentionally applies RF energy for diagnosis or treatment during activation. Observe other electronic medical equipment in the vicinity during the LigaSure activation for any possible adverse electromagnetic effects. Ensure adequate separation of electronic medical equipment based on observed reactions.
The use of accessories, other than specified in the LigaSure User Guide and Service Manual, may result in increased emissions or decreased immunity of the LigaSure.

Voltage Transients (Emergency Generator Mains Transfer)

This generator operates in a safe manner when you transfer between line AC and an emergency generator voltage source.

Guidance and manufacturer's declaration - electromagnetic emissions		
The LigaSure is intended for use in the electromagnetic environment specified below. The customer or the user of the LigaSure should ensure that it is used in such an environment.		
Emissions test	**Compliance**	**Electromagnetic environment - guidance**
RF emissions CISPR 11	Group 1	The LigaSure uses RF energy only for its internal function. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment.
RF emissions CISPR 11	Class A	The LigaSure is suitable for use in all establishments other than domestic and those directly connected to the public low-voltage power supply network that supplies buildings used for domestic purposes.
Harmonic emissions IEC 61000-3-2	Class A	
Voltage fluctuations/ flicker emissions IEC61000-3-3	Complies	

Guidance and manufacturer's declaration - electromagnetic immunity			
The LigaSure is intended for use in the electromagnetic environment specified below. The customer or the user of the LigaSure should assure that it is used in such an environment.			
Immunity test	**IEC 60601 test level**	**Compliance level**	**Electromagnetic environment - guidance**
Electrostatic discharge (ESD) IEC 61000-4-2	+/-6 kV contact +/-8 kV air	+/-6 kV contact +/-8 kV air	Floors should be wood, concrete or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30%.
Electrical fast transient/ burst IEC 61000-4-4	+/-2 kV for power supply lines +/-1 kV for input/ output lines	+/-2 kV for power supply lines +/-1 kV for input/ output lines	Mains power quality should be that of a typical commercial or hospital environment.
Surge IEC 61000-4-5	+/-1 kV differential mode +/-2 kV common mode	+/-1 kV differential mode +/-2 kV common mode	Mains power quality should be that of a typical commercial or hospital environment.
Voltage dips, short interruptions and voltage variations on power supply input lines IEC 61000-4-11	<5% Ut (>95% dip in Ut) for 0,5 cycle 40% Ut (>60% dip in Ut) for 5 cycles 70% Ut (>30% dip in Ut) for 25 cycles <5% Ut (>95% dip in Ut) for 5 sec	<5% Ut (>95% dip in Ut) for 0,5 cycle 40% Ut (>60% dip in Ut) for 5 cycles 70% Ut (>30% dip in Ut) for 25 cycles <5% Ut (>95% dip in Ut) for 5 sec	Mains power quality should be that of a typical commercial or hospital environment. If the user of the LigaSure requires continued operation during power mains interruptions, it is recommended that the LigaSure be powered from an uninterruptible power supply or a battery.
Power frequency (50/60 Hz) magnetic field IEC 61000-4-8	3 A/m	3 A/m	Power frequency magnetic fields should be at levels characteristic of a typical location in a typical commercial or hospital environment.
NOTE: Ut is the a.c. mains voltage prior to the application of the test level.			

Guidance and manufacturer's declaration - electromagnetic immunity			
The LigaSure is intended for use in the electromagnetic environment specified below. The customer or the user of the LigaSure should assure that it is used in such an environment.			
Immunity test	**IEC 60601 test level**	**Compliance level**	**Electromagnetic environment - guidance**
Conducted RF IEC 61000-4-6 Radiated RF IEC 61000-4-3	3 Vrms 150KHz to 80MHz 3 V/m 80MHz to 2.5GHz	7 V 7 V/m	Portable and mobile RF communications equipment should be used no closer to any part of the LigaSure, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter. **Recommended separation distance** d = $0.5\sqrt{P}$ d = $0.5\sqrt{P}$ 80MHz to 800MHz d = $\sqrt{P}$ 800MHz to 2.5GHz Where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer and d is the recommended separation distance in meters (m). Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey, should be less than the compliance level in each frequency range Interference may occur in the vicinity of equipment marked with the following symbol:
NOTE 1: At a 80MHz and 800MHz, the higher frequency range applies. **NOTE 2:** These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.			
a. Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the LigaSure is used exceeds the applicable RF compliance level above, the LigaSure should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as reorienting or relocating the LigaSure. **b.** Over the frequency range 150kHz to 80MHz, field strengths should be less than 7V/m.			

Recommended separation distances between portable and mobile RF communication equipment and the LigaSure

The LigaSure is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The Customer or the user of the LigaSure can help prevent electromagnetic interferences by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the LigaSure as recommended below, according to the maximum output power of the communications equipment.

Rated maximum output power of transmitter (W)	**Separation distance according to frequency of transmitter (m)**		
	150 kHz to 80MHz $d = 0.5\sqrt{P}$	**80MHz to 800MHz** $d = 0.5\sqrt{P}$	**800MHz to 2.5GHz** $d = \sqrt{P}$
0.01	0.05 m	0.05 m	0.1 m
0.1	0.16 m	0.16 m	0.32 m
1	0.5 m	0.5 m	1 m
10	1.6 m	1.6 m	3.2 m
100	5 m	5 m	10 m

For transmitters rated at a maximum output power not listed above, the recommended separation distance d in meters (m) can be estimated using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.

NOTE 1: At 80MHz and 800MHz, the separation distance for the higher frequency range applies.

NOTE 2: These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.

Output Characteristics

Maximum Generator Output

Mode	Maximum Open Circuit Voltage $V_{pp}(V_p)$	Maximum Short Circuit Current* A_{rms}	Maximum Power Setting watts	Crest Factor**
Macrobipolar	760 (380)	2.2	95	1.5
Bipolar	335 (168)	2.2	95	1.5
Seal	575 (288)	4.4	150	1.5

* Open circuit values obtained with a Pearson 411 current measurement with a 1K ohm load attached to the handset.

** Crest factor is an indication of a waveform's ability to coagulate without a cutting effect.

Output Waveform

Macrobipolar/Bipolar	472 ± 5 kHz sinusoid. 100% duty cycle.
Seal	472 ± 5 kHz sinusoid, pulsed.

Figure 4-1.
Output voltage at specific intensity settings in the vessel sealing mode

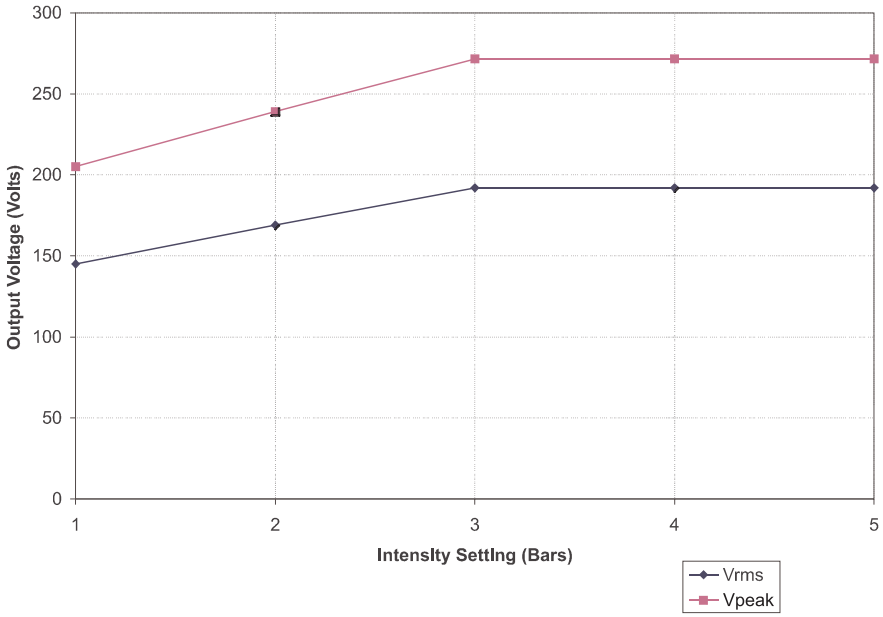


Table 4-1
Open Circuit Output Volts Peak (rms)

Mode	Generator Intensity Setting — Bars				
	1	**2**	**3**	**4**	**5**
Seal	51 (36)	82 (58)	115 (81)	139 (98)	151 (107)

Figure 4-2.
Output voltage at specific intensity settings in the macrobipolar and bipolar modes

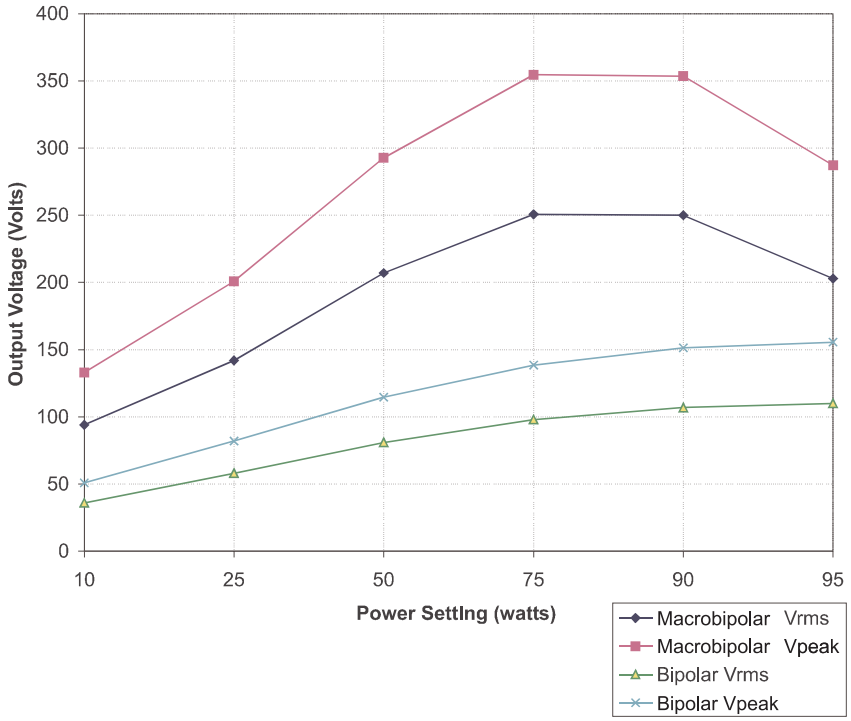


Table 4-2.
Open Circuit Output Volts Peak (rms)

Mode	Generator Power Setting — Watts					
	10	25	50	75	90	95
Macro Bipolar	133 (94)	201 (142)	293 (207)	355 (251)	354 (250)	287 (203)
Bipolar	51 (36)	82 (58)	115 (81)	139 (98)	151 (107)	266 (110)

Output Power vs. Impedance Graphs

The following graphs depict the RF output as applied to tissue impedance for generator operative modes of macrobipolar and bipolar outputs.

Figure 4-3.
Power (in watts) versus impedance (in ohms) in the vessel sealing mode

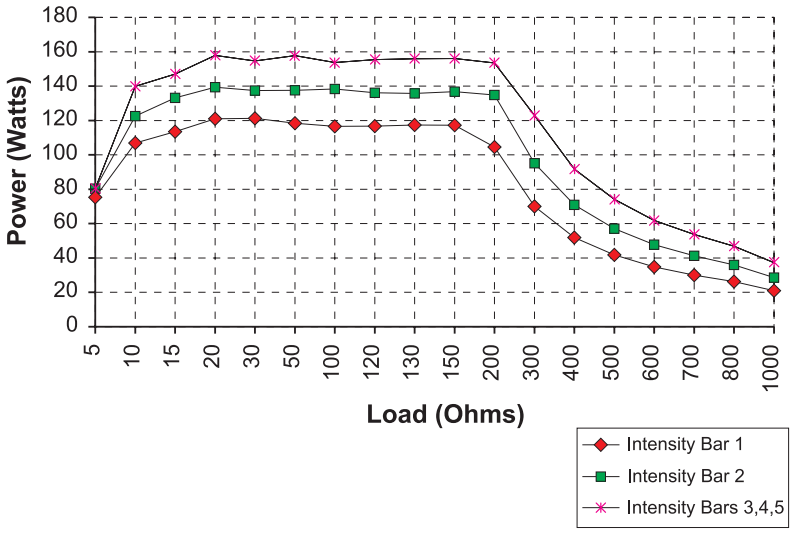


Figure 4-4.
Power (in watts) versus impedance (in ohms) in the macrobipolar mode

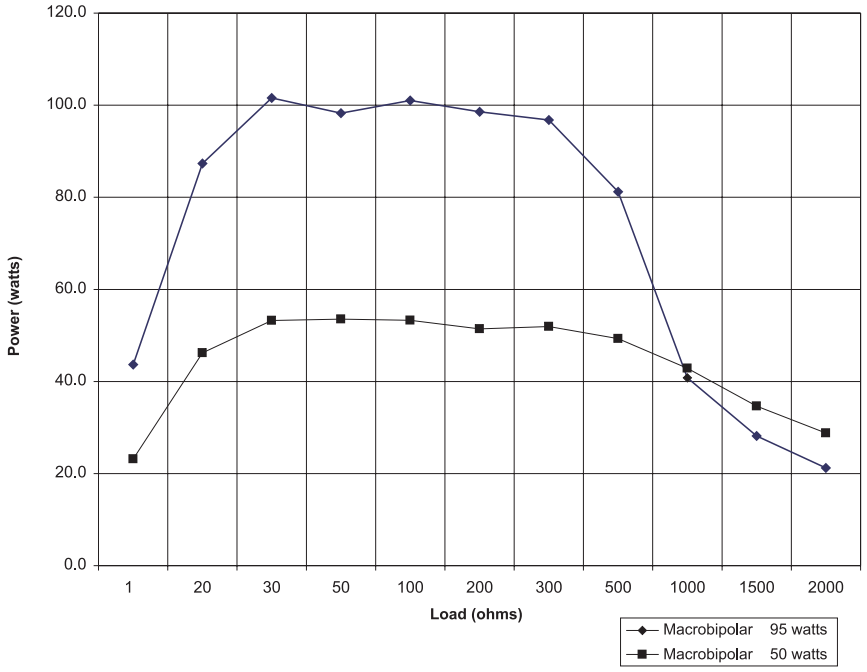
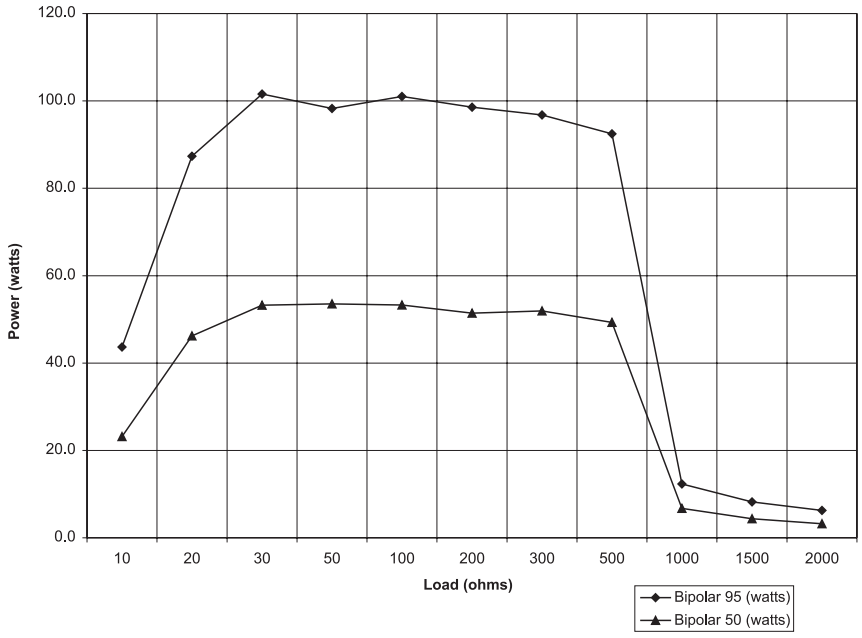


Figure 4-5.
Power (in watts) versus impedance (in ohms) in the bipolar mode



CHAPTER 5

Principles of Operation

This chapter provides detailed information about how the LigaSure vessel sealing generator functions and how the internal components interact.

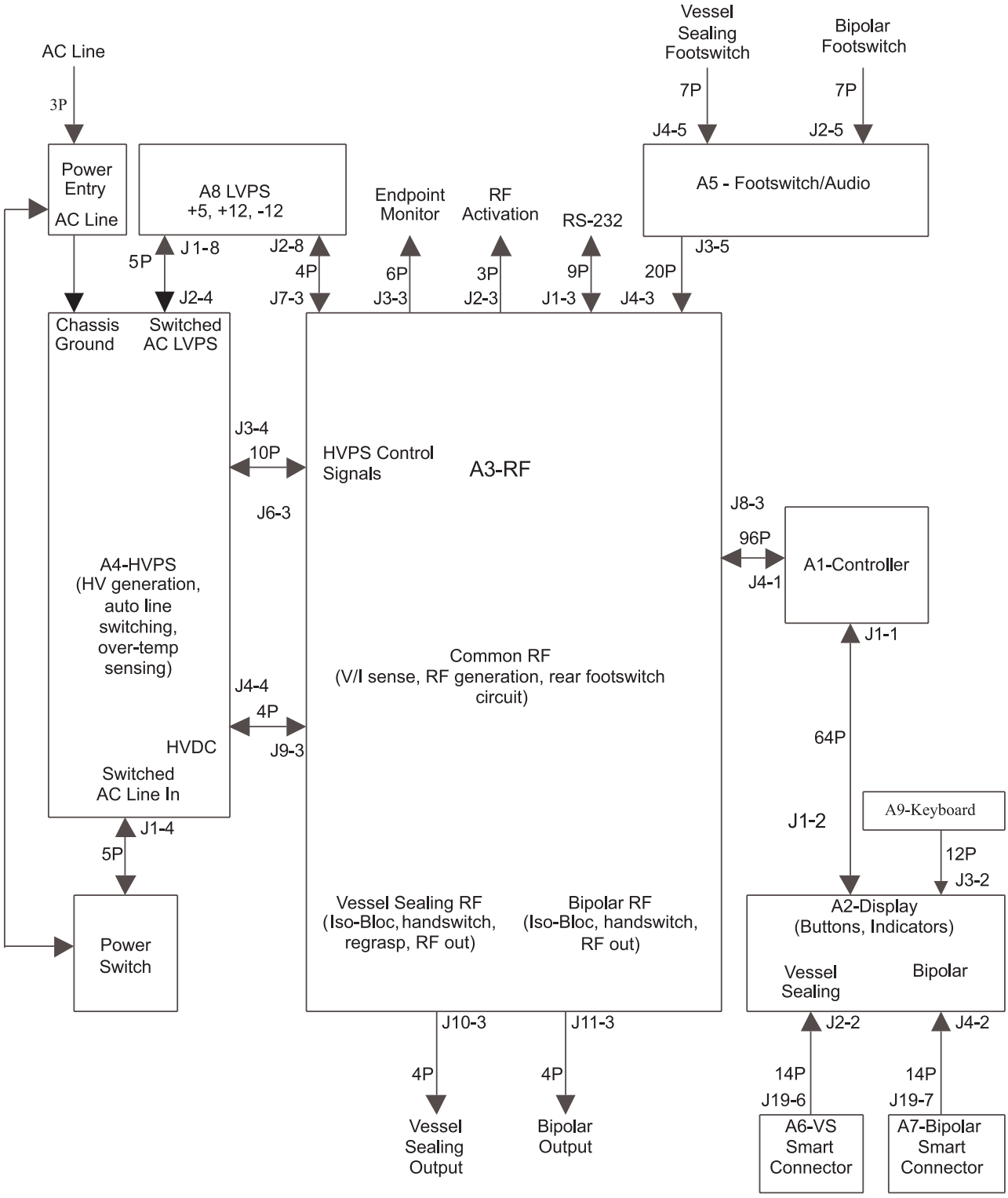
The circuitry resides on eight printed circuit boards: the control board, the display board, the footswitch board, the low voltage power supply board, the high voltage power supply board, the Radio Frequency (RF) board, and two smart connector boards.

This chapter includes the following information:

- A block diagram that illustrates how the generator components interconnect
- A general description of how the generator works
- A detailed description of the circuitry for each printed circuit board

Block Diagram

Figure 5-1.
A diagram of generator component interconnections



Functional Overview

The LigaSure vessel sealing system is an isolated output electrosurgical generator that provides power for vessel sealing and bipolar surgery.

- It includes the following features:
- LigaSure vessel sealing technology
- Vessel sealing regrasp indicator alerts you if the instrument jaws have shorted out, if the system has reached the maximum seal cycle time, or if the tissue impedance is out of range
- Bipolar and macrobipolar modes
- Instant Response technology
- Memory button to recall the most recently used intensity and power settings
- Smart interface for connecting a Valleylab LigaSure handset or smart connector adapter
- Adjustable volume for the activation tone
- Handswitch or footswitch activation
- RF activation port, RS-232 serial port, and expansion port

Vessel Sealing

The LigaSure vessel sealing system provides precise energy delivery and electrode pressure to vessels for a controlled time period to achieve a complete and permanent fusion of the vessel lumen. This system works on isolated arteries and veins up to and including 7 mm in diameter and tissue bundles. The system has been optimized to produce minimal sticking, charring, or thermal spread to adjacent tissue.

Bipolar Operation

Two modes are available:

- Bipolar – for most applications. The LigaSure bipolar system provides tissue dessication with low voltage to prevent sparking. The power remains constant over a specific range of tissue impedance, allowing a consistent tissue effect.
- Macrobipolar – for bipolar cutting or rapid coagulation. The system provides higher voltage and greater power than with the bipolar mode.

Instant Response Technology

The LigaSure generator automatically senses tissue impedance and adjusts the output voltage to maintain a consistent effect across different tissue types. This adjustment is based on the power setting and the level of tissue impedance. The system controls maximum output voltage to reduce tissue damage and to minimize sparking.

Control Board

Refer to Chapter 10, *Service Parts*, for components and the *Schematics Supplement* for system schematics.

The control board contains the circuitry that controls the generator, including the indicators and switches on the display board and the Radio Frequency (RF) output stage on the RF board. Firmware on the control board performs many diagnostic and initialization routines, and reports errors as alarm numbers on the front panel.

The control board interfaces with the RF board through a 96-pin card edge connector. It interfaces with the display board through a 64-pin ribbon cable.

Microcontrollers

Two microcontrollers on the control board control the LigaSure system. These microcontrollers communicate with each other through a shared random access memory (RAM). The main microcontroller (U5) performs all system functions except the feedback control of the generator RF output. The feedback microcontroller (U11), which is a separate, dedicated microcontroller, controls the real-time-critical feedback control of the generator RF output. All system analog signals are available to these microcontrollers.

A third microcontroller (U9) functions as an application-specific integrated circuit, or ASIC. It generates the RF drive waveforms (T_ON\) for the RF output stage.

Main Microcontroller

The main microcontroller (U5) is an 80C562 that incorporates an 8-input multiplexed 8-bit A/D converter. The main microcontroller is responsible for overall system control. It monitors all dosage error functions and safety circuits. It implements the user interface, including activation control. It is primarily responsible for these functions:

- Segment display drivers and LED update
- Power control buttons, mode buttons, and the activation interface
- Serial port interface
- Alarm handling
- Audio control
- Memory control and storage (system alarms with time stamps; calibration values)
- Real-time clock control and interface
- Internal self-tests
- Communicating with the feedback microcontroller

Main Microcontroller Memory

An ST Microelectronics PSD835G2 programmable systems device (U3) provides program memory (512K x 8 external Flash Memory) and data memory (2K x 8 external battery-backed static RAM) for the main microcontroller. Additional data memory is available from these sources:

- 256 x 8 microcontroller internal RAM
- 4K x 8 external static RAM (U4) shared with the feedback microcontroller

Battery-Backed RAM

A socket on the control board contains a 3.0 V lithium button cell battery (BT1). This battery provides backup power for the 2K x 8 external RAM on the PSD835G2 device (U3) used by the main microcontroller. The battery-backed RAM stores calibration constants, last setup parameters, and temporary data.

Feedback Microcontroller

The feedback microcontroller (U11), like the main microcontroller, is an 80C562. It receives commands from the main microcontroller and, when the generator is activated, establishes the appropriate relay closures and activates RF output. It continually adjusts the output signal of the generator by controlling the high voltage DC power supply and the RF clock circuitry. It is primarily responsible for these functions:

- T_ON waveform control
- Constant voltage, current, and power feedback control
- ECON initialization
- Real-time information update (actual voltage, current, power, impedance, effect mode)
- Memory tests
- Communicating with the main microcontroller

Feedback Microcontroller Memory

An ST Microelectronics PSD835G2 programmable systems device (U3) provides program memory (512K x 8 external Flash Memory) and data memory (2K x 8 external static RAM) for the feedback microcontroller. Additional data memory is available from these sources:

- 256K x 8 microcontroller internal RAM
- 4K x 8 external static RAM (U4) shared with the main microcontroller

Shared RAM

An IDT 713425A device (U4) with semaphore flags provides the 4K x 8 external shared static RAM. The shared RAM allows the main microcontroller (U5) and the feedback microcontroller (U11) to share common variables. It functions as a communications interface between the main and feedback microcontrollers. It also provides additional general-purpose RAM to these microcontrollers.

I/0 Expansion

Three devices provide input/output (I/O) expansion capabilities:

- One ST Microelectronics PSD835G2 programmable systems device (U6)
- One ST Microelectronics PSD835G2 programmable systems device (U3)
- One 82C55 expansion port (U2)

The ST Microelectronics PSD835G2 incorporates 52 individually programmable I/O pins divided into 6 ports of 8-bits each and 1 port of 4-bits. Of the general I/O pins, 24 can alternatively be utilized for 24 PLD outputs. The PSD835G2 also contains 512K x 8 Main Flash Memory, 32K x 8 Boot Flash Memory, 2K x 8 of SRAM, and a power management unit for battery backup. The power management unit for battery backup is not used by the Feedback microcontroller. The I/O expansion capabilities of the Feedback PSD835G2 has a built-in IEEE 1149.1 compliant JTAG serial port to allow full-chip in-System Programmability (ISP). The Main PSD835G2 is #1 on the JTAG chain and the Feedback PSD835G2 with the exception that the 512K x 8 Flash Memory for the Main PSD835G2 is accessed in a bank switching methodology and the I/O expansion capabilities are configured as outputs for lamp control, keyboard scanning, and chip selects.

The 82C55 is a generic I/O expander which incorporates 24 I/O pins divided into 3 ports of 8-bits each. The 82C55 is configured as all inputs, and is used to read the keyboard, keying signals, accessory switches, and system status flags.

Keyboard Interface and Activation Inputs

The keyboard interface is a simple row and column matrix between three bank select output lines (BANK0–BANK2) on port A of the PSD835G2 (U3). The main microcontroller and eight keyboard (KBD_D0–KBD_D7) input lines on port A of the expansion port 82C55 (U2) use this interface.

Port B of the expansion port 82C55 reads activation inputs from the IsoBloc decoding circuits on the RF board.

Power Supply Supervisor Circuit

The power supply supervisor circuit (U14), a MAX691, generates a Reset signal and a Reset\ signal for the main microcontroller (U5) if the power supply voltage to the control board drops below 4.65 V. It also generates a voltage sensitive chip select for the PSD835G2 (U6) and the PSD835G2 (U3). The low voltage threshold (4.65 V) places U3 and U6 in sleep mode and disables the 2K x 8 external static RAM.

A/D and D/A Conversion

Each 80C562 microcontroller (U5 and U11) contains an 8-channel multiplexed 8-bit analog-to-digital (A/D) converter. Incorporating fixed gain control in the sense circuits on the RF board and prescaling based on the expected input voltage or current values enhance the resolution of voltage and current sense inputs.

An MP7226 quad digital-to analog (D/A) converter (U15) provides 4-channel 8-bit D/A capabilities for the feedback microcontroller to output 0 to 5 Vdc analog voltages.

Waveform Generation (T_ON)

A dedicated 89C54 microcontroller (U9) generates the RF drive waveforms (T_ON\) for the RF output amplifier on the RF board. The microcontroller functions as an application-specific integrated circuit (ASIC), performing an endless series of repetitive tasks while enabled.

The feedback microcontroller (U11) holds the T_ON microcontroller (U9) in a reset state until the feedback microcontroller detects a valid activation request. After validating the request, the feedback microcontroller releases the T_ON microcontroller from reset and communicates a 4-bit code - 0 - that represents the generator mode to be activated.

The code generates a unique waveform pattern to be delivered to the RF output stage of the generator. The T_ON microcontroller reads and evaluates the code and, if the code value is acceptable, repetitively generates the appropriate waveform until the activation request ends. After the request ends, the feedback microcontroller places the T_ON microcontroller back into reset.

If the code received by the T_ON microcontroller is not valid, the internal program sets an error flag, deactivates all output signals, and remains in an error state until the user resets the system.

T_ON Average Check

A capacitor filters the T_ON waveform generator output, returning it to the main microcontroller as a DC voltage value called T_ON average. Each distinct output mode of the T_ON waveform generator produces a different T_ON average. The main microcontroller continually checks the T_ON average for compliance with the calibrated value to ensure that the T_ON waveform generator is operating properly.

The T_ON average signal rests at 5 V when the generator is not activated and drops to the calibrated value when activation occurs. The main microcontroller checks to make sure the T_ON average signal is within ± 15 counts of the calibrated value.

Audio Alarm

The audio alarm circuit resides on the footswitch board. Both software and hardware control the audio alarm.

- The feedback microcontroller, in response to activation inputs, alarms, and power-up, writes to a digital-to-analog converter (DAC) chip, U15, which generates an analog control signal, V_FREQ. This signal provides software control for the audio alarm. The V_FREQ signal connects from the control board to the RF board through the 96-pin connector, and then from the RF board to the footswitch board through the 20-pin footswitch ribbon connector.
- The RF_TONE\ signal provides hardware control. RF sensing circuitry on the RF board generates the RF_TONE\ signal in the RF output stage.

Serial Interface

The RS-232 serial port is a software-polled interface to the main microcontroller (U5). You can use it for diagnostics and calibration. Transmission and receipt of command strings do not stop real time processing, except as single characters are read from or written to the serial port. The serial port configuration follows:

- 9600 baud
- 8 data bits
- 1 stop bit
- no parity

This timing is derived from the main microcontroller oscillator frequency of 11.0592 MHz.

The control board serial port signals connect to the RF board through the 96-pin connector. The signals then connect to the 9-pin serial port connector on the RF board.

Dosage Error Algorithm

The basis of the dosage error algorithm for the closed loop modes (bipolar and seal) is a comparison between two microcontroller/sensor sets:

- Main microcontroller, current and voltage sensors
- Feedback microcontroller, current and voltage sensors

While the feedback microcontroller operates the generator, the master microcontroller continuously monitors generator operation, calculating and checking several values:

- Voltage and current input to the microcontrollers
- High voltage control signal
- High voltage sense signal
- Desired value (entered at the front panel) at the main microcontroller
- Desired value (entered at the front panel) at the feedback microcontroller

The master microcontroller, using the dosage error algorithm, checks to make sure the feedback microcontroller is operating the generator within specific parameters:

- During idle, the main sensors receive less than 50% of full scale.
- The high voltage (HV) power supply board control signal is greater than 90% and the V/I signals are less than 10% of full scale.
- The HV power supply and the HV sense signals are within one volt of each other.
- The power readings at the main and feedback microcontrollers do not differ by 50 watts or more.
- Sensors connected to the main microcontroller are *not* stuck at 100% of full scale.
- Desired power at the main and feedback microcontrollers are the same.
- Actual power is below the error threshold as defined by IEC 60601-2-2, Dosage Error Limits.

If the algorithm detects that the generator exceeds one or more these parameters, it signals an error condition. The system displays an error message and shuts down all generator output.

Instant Response Algorithm

This algorithm controls the current, power, and voltage adjustments for all modes.

Controlling the maximum output voltage reduces high frequency leakage, reduces video interference, and minimizes sparking. At low impedances, keeping the current constant protects output circuitry. At high impedances, keeping the voltage constant limits arcing and electro-magnetic interference.

Constant Current

The algorithm holds output current constant according to this equation:

I = (P/R) ˆ(1/2)

where I is the output current, P is the power set by the user, and R is the constant current to constant power impedance switchpoint.

Constant Power

The algorithm maintains the power set by the user.

Constant voltage

The algorithm controls the output voltage according to the following equation:

V = (P*R) ˆ(1/2)

where V is the output voltage, P is the power set by the user, and R is the constant power to constant voltage impedance switchpoint. In some high impedance conditions, the algorithm modifies this equation to reduce voltage more rapidly.

Front Panel

The front panel consists of an injection molded plastic bezel with a membrane keyboard, power switch, and seal and bipolar smart receptacles. These front panel components connect to the display board and the RF board.

Membrane Keyboard

A high strength adhesive attaches the membrane keyboard to the bezel. The keyboard is not removable. The membrane contains 16 metal dome push-button switches. Six of these switches control the up and down sequencing of the power seven-segment and bar lamp light-emitting diodes (LEDs). One switch controls the Memory function, which stores previous settings.

The membrane also contains three illumination window LEDs, one for each RF activation mode. A 12-pin flat ribbon cable connects the membrane keyboard switches and LEDs to the display board.

Power Switch

A double pole single throw switch snaps into the front of the bezel. This switch connects the AC mains to supply power to the generator.

Display Board

Refer to Chapter 10, *Service Parts*, for components and the *Schematics Supplement* for system schematics.

The display board resides in the front panel assembly. It contains RF indicator lamps, seven-segment LED power setting displays, seal bar lamp setting displays, and a regrasp indicator lamp. The display board switch circuitry includes the LED and lamp driver circuitry, power selection switches, mode selection switches, and the smart switch LED driver circuit.

RF Indicator Lamps

The RF indicator lamps illuminate during RF activation to indicate the presence of RF power. Two incandescent bulbs illuminate each of the three indicator bars (seal, bipolar, and macrobipolar) on the front panel.

- LP11 and LP12 illuminate the blue bipolar bar, indicating bipolar activation.
- LP7 and LP8 illuminate the light blue macrobipolar bar, indicating cut activation.
- LP3 and LP4 illuminate the blue seal bar, indicating seal activation.

The BIP_LMP, MACRO_LMP, and VS_LMP signals control the RF indicator lamps. These signals originate from port A of the main microcontroller programmable peripheral (U3) on the control board.

Q1 through Q4 MOSFETS turn the RF indicator lamps on and off. Resistors R4, R5, R9, R10, R13, and R14 set the amount of current flowing through the lamps when they are turned on. The value of these resistors varies for each indicator bar, depending on the color of the bar, to make the different colors of the bars illuminate with equal intensities.

LED and Seven-Segment Display Drivers

This circuit contains two display drivers: the LEDs and the seven-segment displays. The bar lamp LEDs indicate the seal intensity. The seven-segment displays indicate the bipolar and macrobipolar power settings.

Each display driver (U10 and U11) can drive up to eight banks of eight LEDs by multiplexing the time at which it turns on each bank and controlling how long the bank remains on. Wiring the banks together increases the time that a group of LEDs can remain on, effectively increasing the brightness of that group.

U10 drives the discrete bicolor LEDs. These include the red and green indicators for the smart connectors in the bipolar and seal modes. The anode of each mode selection LED connects to driver U10. Using pairs of the driver digit lines makes the effective duty ratio for these LEDs 1/4.

U11 drives the seven-segment displays that indicate power settings. U5 and U6 indicate the bipolar power setting; U2 and U3 indicate the macrobipolar power setting; and U1, U4, U7, U8, and U9 indicate the seal intensity bar lamp setting. Seal bar lamp U12 illuminates yellow when you turn the power on and the system completes its self-diagnostic test successfully. The yellow lamp setting corresponds to a default seal power setting of zero output. The anodes of these displays each connect to only one digit line of the driver. The effective duty cycle is 1/8 for each seven-segment display.

Some filtering components are associated with U10 and U11. Bypass capacitors C3, C4, C5, C6, C8, and C9 connect between + 5V and DGND. C3, C5, C6, and C8 have a relatively small capacitance value (0.1 µF or less) to filter higher frequency noise. C4 and C9 have a relatively large capacitance value of 47 µF to supply the large spikes of current for the LEDs generated by the multiplexing action of the drivers, which typically occurs at 250 Hz.

Resistor components R16 through R22 and R31 reduce the input impedance of the display driver inputs as seen by the main microcontroller on the control board. This rounds off the edges of these digital signals, reducing high frequency emissions. The lower impedance also reduces the susceptibility of the circuit to noise from other circuits.

Regrasp Display

Q4 drives the discrete LP1 regrasp lamp on and off with seal mode operation only. When Q4 is on, resistor R8 controls lamp LP1 current to control lamp brightness. When received from the control board, a positive TTL level signal activates this display.

Mode Select and Power Control Switches

The mode select and power control switches operate in an 8-bit control format:

Bits	No. of Wires	Purpose
6	2, in pairs	1 pair for each of three operative modes: seal, bipolar, and macrobipolar
1	1	memory recall function
1	1	BANK_0, enables the keyboard membrane

The main microcontroller selects the BANK_0 enable switch through this path:

Port A (on the control board programmable peripheral, U3)
through
Connector J1
to
BANK_0 enable switch

When turned on, MOSFET Q5 activates the keyboard switches.

Command control signals KBD-01 through KBD-06, originating in the control board, choose the up and down power select bit lines:

Command Signals	Function
KBD-01 and 02	Up/Down seal intensity select
KBD-03 and 04	Up/Down macrobipolar power select
KBD-05 and 06	Up/Down bipolar power select
KBD-00	Memory recall select

To read the switches, the main microcontroller enables BANK_0 and reads the state of the keyboard switch return lines, KBD-00 through KBD-06 through the following path:

BANK_0 enable switch
through
Connector J1
to
Port A (on the control board I/O expansion port, U2)

Footswitch Board

Refer to Chapter 10, *Service Parts*, for components and the *Schematics Supplement* for system schematics.

The footswitch board resides inside the rear panel. It contains decode circuitry for accepting and decoding footswitch inputs and an audio circuit for announcing generator activation and various alarm tones. The footswitch board interfaces with the RF board.

Footswitch Decode Circuit

Two bipolar footswitch connectors, mounted on the footswitch board, extend through the rear panel. These footswitch connectors (J2 and J4) accept bipolar and seal footswitch plugs and provide footswitching capability to activate and deliver RF energy to the instrument receptacles on the front panel. The bipolar footswitch connector (J2), color coded blue, mates with the chassis rear panel receptacle highlighted by a blue annular ring. This dual pedal footswitch, connected to J2, allows the delivery of macrobipolar and bipolar RF energy for tissue cut and coagulation.

The bipolar footswitch connector (J4), color coded purple, mates with the chassis rear panel receptacle highlighted by a purple annular ring. This dual pedal footswitch, connected to J4, allows the delivery of seal and bipolar RF energy for tissue sealing and coagulation.

As required by the IEC, the footswitch circuit is isolated from patient connected and ground referenced circuits and is able to withstand a potential of 500 Vrms (50/60 Hz). To obtain this isolation, an isolated power supply (U3) powers the footswitch connected circuitry. The isolated power supply, an HPR-107, operates from the ground referenced +12 V power supply and supplies an isolated 12 volts.

Resistors R12 and R27 form a voltage divider that yields a reference voltage signal (Vref2) of approximately 6 volts. This reference voltage goes to the noninverting inputs of comparators U1A, U1B, U2A, U2B, and U6A.

The common terminal of each footswitch connects to the +12 V isolated power source. Footswitch activation applies +12 V to a resistor divider network. The values of the resistors in the input divider combine to provide a switching threshold of approximately 750 ohms, dividing the +12 V signal. The divided voltage then goes to the inverting input of one of the five comparators (U1A, U1B, U2A, U2B, or U6A). When the voltage at the inverting input exceeds the voltage at the noninverting input, the open collector output of the comparator turns on, causing current to flow in the LED of the corresponding optoisolator. This current generates an infrared (IR) beam that causes an associated photo-transistor to conduct. The collectors of the transistors connect to input pins of an I/O port on the microcontroller where they activate the desired mode of operation.

Audio Circuit

The audio system consists of an audio oscillator, tone control signals, a volume control potentiometer, an audio amplifier, and a speaker.

The audio circuit sounds a tone when RF output is active and a different tone when alarm conditions occur. A potentiometer (R19) allows you to adjust – but not turn off entirely – the volume of RF output activation tones. You cannot adjust the volume of the alarm tone.

When pulled low, the RF_TONE\ signal turns on diode D1 and actively shuts off MOSFET Q1 to enable the audio oscillator, U4.

The feedback microcontroller supplies an analog level control signal, V_FREQ, that determines the output frequency at U4, a voltage controlled oscillator. V_FREQ varies in amplitude to provide the appropriate audio tone.

Normal activation tones are mode dependent and have the following typical operating frequencies:

Mode	Frequency (Hz)
Seal	440
Macrobipolar	520
Bipolar	660

Audio IC U5 amplifies the activation tone signal from U4. Potentiometer R19 allows audio volume control.

The ALARM signal interrupts the activation tone and resets the volume to a fixed level. U7A and U7B are configured in an exclusive OR arrangement that is interactive with volume potentiometer R19.

Under normal operating conditions, the ALARM signal is low, the U7A output floats, and the U7B output transistor remains on. The output of U7B creates a voltage divider through R5, R19 (the volume control potentiometer), and R6 to attenuate the audio signal to levels acceptable for input to the audio amplifier. R6 determines the maximum audio volume and R5 determines the minimum audio volume. R35 determines the audio alert volume level. R7 provides an alternate audio signal path in the event of an open volume control potentiometer.

When the ALARM signal is high, the U7A output transistor is on and the output of U7B floats. The U7A output transistor, when on, pulls R35 to ground and creates a fixed voltage divider with R6 to produce the alarm volume level at the input to audio amplifier U5. Meanwhile, the output of U7A floats, thus removing the variable resistor divider from the circuit. In this case, the volume control potentiometer becomes a small resistance in series with the high impedance input from the audio amplifier, negating the effect of the volume setting.

Audio amplifier U5 and speaker SP1 constitute the final stage in the audio system. C13 AC couples the audio signal to the amplifier. When its gain select pins float, the voltage gain of U5 is about 20. Because the U5 output signal is internally biased to Vcc/2, it is necessary to AC couple the speaker through C16 to prevent the amplifier from DC biasing the speaker.

High Voltage (HV) Power Supply Board

Warning

Potentially lethal AC and DC voltages are present in the AC line circuitry and high voltage DC circuitry described in this manual. Take appropriate precautions when testing and troubleshooting this area of the generator.

The high voltage power supply contains the power entry circuitry, auto mains switching circuitry, AC/DC conversion circuitry, and a DC/DC switching regulator.

Power Entry Circuit

The power entry circuit consists of an integral three wire power cord receptacle, fuse drawer, EMI filter, and a separate power switch. The power switch resides on the front panel; the receptacle/filter, on the rear panel of the generator. You can change AC line fuses, located in the receptacle/filter, from the rear of the generator.

Auto Mains Switching Circuitry

The auto mains switching circuit detects the AC line voltage level and controls the triac (D1). This triac controls the topology of the AC/DC converter. For 120 Vac operation, the triac is on, which connects the AC neutral to the center of the AC/DC converter capacitor network (C17 and C25). In this configuration, the circuit acts as a doubler using the right half of the bridge rectifier (CR3). For 240 Vac operation, the triac is off and CR3 becomes as a full wave rectifier.

The control IC (U5) functions as follows: The series circuit (CR7, R48, R49, and C28) provides power for U5. Pin 1 (Vss) is a shunt regulator that provides a –9 V (nominal) output. The divider (R40 and R41) measures the input line voltage. Since the voltage at pin 8 varies with the line, it can sense the line voltage zero crossing as well as the peak voltage. Pins 2 and 3 are inputs to an oscillator used for triac triggering timing. R42 and C26 set the oscillator frequency. Pin 7connects to Vss, which places the circuit in the fail-safe mode. Thus, once the circuit enters full bridge mode, it remains in that mode until the user recycles input power. A power dropout cannot cause the circuit to accidentally act as a doubler when the generator receives the higher input voltage range.

AC/DC Converter

The AC/DC converter uses CR3 as either a doubler or a full wave rectifier, depending on the input voltage. In either case, an unregulated nominal 340 Vdc is provided to the DC/DC switching regulator. Thermistors R28 and R29 provide inrush current limiting, and fuse F1 provides protection against faults in the DC/DC switcher.

Capacitors C17 and C25 function as an energy storage reservoir for the DC/DC switcher. C23 and C24 function as a high frequency bypass filter. Bleeder resistors R46 and R47 discharge the capacitors when the user disconnects the AC line or turns off the power switch.

DC/DC Switching Regulator

The DC/DC switching regulator is a buck derived, pulse width modulated (PWM) system. It is an isolated, fixed frequency, full bridge forward converter. The PWM IC (U4) functions in the voltage mode. The output of the regulator is adjustable from approximately 0 to 120 Vdc.

The regulated power supply incorporates a full H bridge and consists of four power MOSFETs (Q3, Q4, Q5, and Q6) that operate at AC line potential. Transistors Q3 and Q4 are on while Q5 and Q6 are off, and the reverse. In this manner, power signals to the power transformer are bidirectional, or push-pull. This allows full use of the transformer core magnetization capability. Modulating the time that each MOSFET pair is on achieves regulation. Capacitor C35 in series with the power transformer T3 primary prevents DC flux imbalance. A snubber circuit (C22 and R35) absorbs resonant harmonic energy spikes. Another snubber circuit (C32, R50 and C33, R51) reduces spikes due to reverse recovery of the output rectifier, CR8. Bidirectional transient suppressor, TS1, limits high voltage spikes by detuning the snubber circuit and protecting CR8 from reverse excess PIV transients.

The gate driver circuitry for each MOSFET, transformer-coupled through T2 and T4, provides AC line isolation. It consists of a dual MOSFET driver (U1) and various damping resistors. Resistors R16, R26, R44, and R53 minimize turn on/off delay and damp on/off ringing. Blocking capacitors C6 and C34 prevent DC flux imbalance in T2 and T4. Resistors R15 and R52 limit the turn-on surge of the H bridge MOSFET components.

A high voltage diode, CR8, provides full wave center tap rectification for the output of the power transformer. L1, C30, and C31 filter the rectified power signal. The regulated HVDC output from this supply is the input power to the RF stage of the generator.

The SYS_ECON signal from the microcontroller controls the output voltage level. This 0 to 5 Vdc signal sets the reference for the PWM control loop. An external op-amp (U2) buffers the SYS_ECON signal and provides error amp control of the PWM switcher for stable closed loop performance. Closed loop control results from comparing the feedback voltage from the output divider (R2 and R3) to the ECON input signal.

The output of U4 is a pair of complementary signals that are pulse width modulated by comparing ECON with the internal oscillator ramp waveform. At the start of an oscillator cycle, the U4 output turns on. It turns off when the ramp voltage crosses the ECON level. The two output signals from U4 (pins 11 and 14) feed the MOSFET drivers (U1A and U1B).

R20 and C12 set the U4 oscillator frequency to approximately 82 kHz. C13 controls the pulse width duty at power on for slow start control. Transformer T1 monitors the power transformer primary current, protecting against faults in the DC/DC switcher power stage and faults in the output load circuitry. CR1, CR2, CR5, and CR6 rectify the output of T1; R24 and C21 filter it. This filtered signal goes to the current limit pin (pin 9 of U4). During an overcurrent condition the U4 current limit function resets the HVDC output to a low voltage level (around 10Vdc) until the current falls. Pin 9 of U4 also allows remote shut down of the DC/DC switcher through Q1 and CR4. The shut down signal, labeled HV_ENABLE, comes from the main microcontroller on the control board.

The resistor divider on the high voltage DC output formed by R5 and R37 provides dosage error sensing, identified as HV_SEN, to the control board.

Thermal Sensing (High Temperature Limit)

A reference voltage determined by R9 and R11 goes to the non-inverting input of comparator U3B. High temperature limit control occurs when the temperature of the NTC thermistor R22 reaches approximately 65° C, which causes the inverting input of comparator U3B to drop below the reference voltage and trip the TEMP_HI signal. Resistor R10 provides positive feedback causing approximately 10° C of hysteresis between heating and cooling thermal sense activation.

When the main microcontroller reads the TEMP_HI signal, it flashes number 451 alternately with the power settings. This disables the generator and prohibits any RF output from occurring. When the temperature drops to approximately 55° C, the circuit reverts to its low temperature state, and normal operation resumes.

Low Voltage Power Supply

The low voltage power supply is a medical grade triple output supply rated for 40 watts. It delivers a regulated +5 Vdc and ±12 Vdc output with current limit and overvoltage protection. This power supply incorporates universal mains switching which automatically adjusts for both 120 Vac and 240 Vac input voltage ranges. The low voltage power supply provides low voltage power to the RF board at connector J7. The following table shows the J7 connector pinouts:

PIN	Voltage	Test Point
1	+5 Vdc	TP4
2	–12 Vdc	TP3
3	+12 Vdc	TP2
4	GROUND	TP1

The low voltage power supply specifications are as follows:

Output Voltage	Output Current	Output Power*
+5 Vdc	4000 mA	20.0 W
–12 Vdc	400 mA	4.8 W
+12 Vdc	2000 mA	24.0 W

* Total output power cannot exceed 40 W.

RF Board

Warning

High frequency, high voltage signals that can cause severe burns are present in the RF output of the LigaSure generator. Take appropriate precautions when testing and troubleshooting the output circuitry of the generator.

The RF board incorporates a variety of processing circuits for the LigaSure generator, providing the key function of generating the output RF energy for all operative modes. It also provides the main integration function for all sub-assemblies interfaced within the LigaSure generator.

The following list identifies all the operative modes, process circuits, and integration functions provided by the RF board assembly:

- Operative modes
    - seal
    - macrobipolar
    - bipolar
- RF driver circuit
- RF output circuit
- RF output relays
- EKG output relay
- Primary sense circuits
- Redundant sense circuits
- Single fault protection circuit
- Heat sink
- Isobloc circuit
- Integration functions
    - low voltage power supply interface
    - controller Interface
    - high voltage power supply interface
    - footswitch interface
    - handswitch interface
    - expansion port
    - RS 232 interface

Operative Modes

The LigaSure generator provides three modes of operation, each of which delivers bipolar RF energy through two front panel output receptacles. The seal, macrobipolar, and bipolar modes develop RF energy derived from a common RF source, located on the RF board. All modes provide output at a fixed frequency of 472.8 khz, providing an RF signal with either a continuous or pulsed mode sinusoid waveshape.

In the seal mode, the developed RF energy originates at capacitor C59. Multiplexed by relays 1b and 6b, the RF signal developed across capacitor C59 goes to RF board output connector J10. From connector J10, a cable carries the RF energy to the front panel output receptacle, identified by the LigaSure logo, on the left side of the generator. The seal mode output RF signal exhibits a pulsed mode sinusoid waveshape. Closed loop software control initiated by the embedded microcontroller board determines pulsed mode operation.

In the macrobipolar mode, the developed RF energy originates from the cumulative output of a capacitor ladder network. Capacitors C58, C62, C59, C65, and C66 form this ladder network to generate the macrobipolar output, multiplexed through relays 2b and 3b, to RF output connector J11. From connector J11, a cable carries the RF energy to the front panel bipolar output receptacle, located on the right side of the generator below the macrobipolar and bipolar power display. The macrobipolar mode RF output signal exhibits a continuous sinusoid waveshape. The developed RF output voltage is greater than the seal or bipolar mode outputs and has a unique power curve profile to cut tissue. The microcontroller monitors the macrobipolar output and provides closed loop control by sensing the tissue impedance and automatically adjusting the output to achieve the desired clinical effect.

The bipolar mode RF operates from the same point of origin as the macrobipolar mode. Its output, multiplexed through two pairs of relays, goes to both the seal and bipolar front panel output receptacles. Relays 2b and 3b route the bipolar RF to connector J11 for output energy distribution through the bipolar output connector, while relays 4b and 5b route the bipolar RF to connector J10 for energy distribution through the seal output connector. The microcontroller determines the correct distribution of the bipolar energy based on footswitch and handswitch activation requests. The bipolar mode RF output signal also exhibits a continuous sinusoid waveshape with a unique power curve profile to coagulate tissue. The microcontroller monitors the bipolar output and provides closed loop control by sensing the tissue impedance and automatically adjusting the output to achieve the desired clinical effect.

RF Driver

The RF driver circuit processes a T_ON\ gating signal which enables the RF generator within the LigaSure unit. The T_ON\ signal, a TTL level pulse train signal, originates in the microcontroller. T_ON\ has a 60% duty cycle active high pulse waveshape. When activated, T_ON\ starts RF energy development with either handswitch or footswitch requests.

On the RF board, integrated circuit chips U2 and U11 process the T_ON\ signal. U2 is a quad NAND gate chip configured as a tri-state buffer that allows one of two actions:

- Process the T_ON\ signal to start an RF output.
- Inhibit the T_ON\ signal to disable the RF output if the system detects a single fault failure in the RF output.

U11 is a power MOSFET driver chip that processes T_ON\ by converting the TTL level signal to a 12 V pp signal. This 12 volt signal drives Q5, the power MOSFET RF generating component. TP12 provides a test point inverted T_ON\ signal at the gate of Q5 with a 40% duty activation. U11 receives power from U10, which has an output permanently set high for all RF activation modes.

RF Output

The RF output circuit develops the energy for all operative modes of the LigaSure generator. The circuit consists of a resonant tank network: T7, L1, L2, C57, C63, C58, C62, C59, C65, C66, C60, and power MOSFET Q5. RF energy results when the T_ON\ signal, with a high voltage DC (HVDC) source present at test point TP13, switches device Q5 on and off. HVDC, originated by the high voltage power supply, provides source power for the RF output stage. When switched on/off to develop RF, Q5 creates a signal that exhibits a half-sine waveshape of approximately 350 volts peak amplitude. This signal represents the result of resonant action that occurs between the inductive and capacitive components in the RF output circuit. The half-sine period timing is typically 800 ns for unloaded generator output. Under load, when the generator applies RF energy to tissue, the half-sine period timing increases to a maximum of 1.25 µs. The half-sine waveshape is periodic, repeating every 2.115 µs with the on/off switching of Q5.

The half-sine signal appears at test point TP11. Resonant action between inductive and capacitive components converts the half-sine signal to a continuous sinusoid RF output.

Components TS1, TS2, and TS3 provide hardware overvoltage limiting to the RF output. These components turn on and off automatically as the output peak voltage exceeds the maximum output operating voltage of 203 Vrms. TS1, TS2, and TS3 are bidirectional transient suppressor devices that limit overvoltage to approximately 245 Vrms. To arrive at the 245 Vrms limit, the system sums TS1, TS2, and TS3.

RF Output Relays

Based on footswitch or handswitch requests, relays RL1 through RL6 multiplex the developed RF energy for distribution to the seal and bipolar output receptacles.

Command signals originating in the microcontroller route to the RF board to relay driver chip U12. Upon receiving a positive logic +5 V signal request to the input of U12, the relay driver output goes low to energize the respective relays and close the relay switch contacts. Relay switch closure, which provides bipolar RF energy to the output, is equivalent to a double pole single throw switch. This avoids a potential patient hazard by eliminating RF energy on any output receptacle pins when footswitch and handswitch requests are not active.

The method of output relay switching is cold switching the relay contacts. Cold switched relay contacts make and break contact connections when no RF voltage or current is present. This promotes an increased life cycle and an increased mean time between failure (MTBF) for the relay by avoiding the excess contact burn and premature contact failure experienced with hot switched relay activations.

The following table identifies the output relays activated by the microcontroller command signals. It also identifies the RF output energy delivered to the respective output receptacles.

Command Signal Inputs to U12		Output Relays Switched	RF Energy Delivered	Output Receptacle RF Activation
Pin	**Signal**			
1	VSRF/ Vout_RLY	RL1A, RL6A	Seal	LigaSure
2	BPRF/ Vout_RLY	RL4A, RL5A	Bipolar	LigaSure
3	BPRF/ Bout_RLY	RL2A, RL3A	Bipolar	Bipolar
4	RFACT_RLY	K1B	None	None

EKG Output Relay

The previous table also lists a relay that does not actively switch RF energy. A positive +5 V signal, represented by the RFACT_RLY command input from the microcontroller to U12, energizes relay K1B. Relay contact K1B provides isolated SPST switch contact closure when the system generates and delivers any RF energy in any operative seal or bipolar mode. The K1B switch contact closure communicates to peripheral equipment in the operating room that RF energy is present.

Primary Sense Circuits

The primary sense circuits provide generator output voltage and current monitoring to the feedback microcontroller for all operative seal and bipolar modes.

Precision absolute value processing circuits, which provide non-contact magnetic coupling to the RF output, implement RF output sensing. Two factors maintain high accuracy and precision:

- Op-amp compensation for non-linear diode elements
- Identical voltage and current sense topology.

The primary sense circuits contain the following components:

Unit	Description/Function
T1	Current transformer - provides non-contact RF tank current monitoring to establish a weighted measure of the RF output voltage
T2	Current transformer - provides non-contact RF output current monitoring
U5	Op-amp - provides absolute value circuit processing of the signal recovered from R44, originating from T1
U6	Op-amp - provides absolute value circuit processing of the signal recovered from R45, originating from T2

The circuits of U5 and U6 provide absolute value processing with a transfer gain of one. This offers maximum stability and precision, and places the correlation of developed RF output voltage and current on resistors R44 and R45.

V_SEN and I_SEN signals then go to the microcontroller to provide closed loop feedback that the actual power delivered matches the requested power as displayed on the front panel.

Redundant Sense Circuits

Redundant voltage and current sense circuits provide dosage error monitoring of the delivered RF energy output.

The redundant sense circuits contain the following components:

Unit	Description/Function
T5	Current transformer - provides non-contact RF tank current monitoring to establish a weighted redundant measure of the RF output voltage
T3	Current transformer - provides non-contact redundant RF output current monitoring
CR22, CR23, CR25, CR26	Diodes - provide full wave bridge rectification of the signal recovered from T5
R51	Resistor - provides a proportional measure of the rectified signal of T5. R52 and C48 then low pass filter the R51 signal to develop the VR_SEN redundant voltage monitor.
CR12, CR13, CR15, CR16	Diodes - provide full wave bridge rectification of the signal recovered from T3
R46	Resistor - provides a proportional measure of the recitifed signal of T3. R47 and C46 then low pass filter the R46 signal to develop the IR_SEN redundant current monitor.

Single Fault Protection Circuit

This circuit provides protective mitigation to shut down the RF output if a fault condition occurs in which both the primary V_Sen and the redundant VR_Sen signals go to zero. This avoids a dosage error condition by not allowing the delivery of RF energy without the primary, redundant, or both sense signals providing monitoring control through the microcontroller.

Single fault control shuts down the RF output by deactivating both the RF generator and the high voltage power supply simultaneously.

- It deactivates RF output by inhibiting the T_ON\ signal from pulsing the RF generator power FET Q5. The inhibit action occurs in the logic gating provided by chip U2, configured as a tri-state buffer with inhibit control.
- It shuts down the high voltage power supply using a crowbar action on the SYS_ECON signal, which generates the high voltage DC power sourced to the RF generator. The crowbar action occurs when the Q1 FET turns on. IC chips U4A and U4B monitor the primary V_Sen and redundant VR_Sen levels, comparing these signals against a fixed reference bias voltage to determine a simultaneous mutual fault or zero volt condition. The outputs of U4A, U4B, and the Q3 drain connect together such that the corresponding inputs simulate a wired NOR logic. This implementation is necessary because a zero volt sense signal level, without RF activation, does not constitute a fault.

The single fault protection circuit, therefore, actively evaluates a single fault condition *only* when the RF generator produces RF energy. Two other conditions disable the single fault protection circuit:

- RF startup with footswitch or handswitch requests
- Pulse operation in which seal algorithm control shuts off RF energy

The RF_ACT\ command drives Q3 with active low logic switching, a function of the RF activation requests from either footswitch or handswitch. The circuit components U1, CR1 through CR3, and Q2 provide the necessary signal interface processing of the footswitch and handswitch commands to generate RF_ACT\. In addition to supporting the NOR function logic with U4, the RF_ACT\ command also starts the startup single fault disable by providing an input trigger to the monostable one shot device, U3. With each activation request, U3 actively disables single fault sensing for approximately 360 ms to allow sufficient time for the system to develop RF energy and for the primary and redundant voltage sense circuits to sense the developed energy. During seal mode operation, the control signal VSEN_MON_RE_TRIG, supplied by the microcontroller, also triggers U3.

Heat Sink

The heat sink dissipates heat generated by the T_ON\ switching of power FET Q5. In the normal mounting configuration, the heat sink connects electrically and mechanically to the secondary circuit protective earth-chassis ground.

Caution

The heat sink normally exists at ground potential, posing no safety hazard during RF generator activation; however, take appropriate precautions when testing and troubleshooting this area of the generator.

IsoBloc Circuit

The IsoBloc circuit provides a means of detecting a switch closure in an output accessory while maintaining electrical isolation between the generator output and ground referenced circuitry. This circuit consists of the following components:

- An isolated DC power supply
- A comparator to detect switch closure
- An optoisolator link from the output connected circuitry to the ground referenced low voltage circuitry.

Each handswitching output of the generator is associated with its own IsoBloc power source and isolated signal paths.

Isolated Power Supply

The isolated power supply uses a quasi-resonant flyback mode converter to generate the voltages for operating the IsoBloc circuit. The power supply consists of an oscillator, a resonant flyback transformer stage, and secondary half-wave rectifiers.

The IC chip, U13, configuration is as an astable oscillator, ground referenced with an operating frequency determined by R63, R81, and C91. The U13 output drives the resonant flyback transformer stage through the ON/OFF switching of FET Q6. In the flyback operating mode, resonance occurs because of the tuning created by T8, T9, and C69. A result of the resonance, a half-sine flyback signal, exists on the drain of Q6. T8 and T9 also transformer couple the half-sine flyback signal to the RF generator, patient connective floating RF output. Components CR33, CR36, C94, and C106 then provide the half-sine rectification and filtering to generate the IsoBloc power supply voltages.

The system includes two isolated power supply voltage sources: +V_ISO_1 and +V_ISO_2. These DC voltage sources route their supplies individually to each of the seal and bipolar mode floating handswitch circuits.

Optoisolators

The isolated power supply voltages produced by the IsoBloc circuit connect to the active output terminals of the generator. Handswitch activation results from sensing macrobipolar or bipolar switch closure in a handheld accessory. Comparators U14 and U15 turn on a function of accessory switch closure determined by the operating bipolar mode:

- U14 seal mode
- U15 bipolar mode.

A switch closure provides a reverse polarity voltage to the comparator inputs. This action drives the comparator outputs low, which turns on one of the corresponding optoisolators, OPT 1 through OPT4. The optoisolator connects to an input on the 82C55 expansion port in the main microcontroller circuit, pulling the associated input low. The software interprets this action as an RF activation request, and allows RF energy to be delivered.

Integration Functions

The RF board provides the key integration function for all assembly interconnects internal to the LigaSure generator system. It also provides an output interface to peripheral devices that either monitor RF activation or provide an external means of calibrating the generator through a communication port.

The following table identifies the RF board functional interfaces and connective jacks:

Interface	Location	Pins in Connector	Description
Low Voltage Power Supply	J7	4	Connects the LVPS power input to the RF board for distribution to all other interconnecting assemblies that require +5 V, ± 12 V DC power
Controller	J8	96	Connects the control board, providing all communication necessary to develop and control the LigaSure generator RF energy output
High Voltage Power Supply	J6	10	Connects all necessary control signals originating from the microcontroller to generate HVDC source power for the RF generator
Footswitch	J4	20	Provides a signal interface to the footswitch audio board, routing footswitch RF request and audio tone control signals between the footswitch and control boards
Handswitch (RF output receptacles)	J10, J11	5	Couples all handswitching requests to generate macrobipolar and bipolar RF. The optoisolator handswitching signals interface directly with the J8 microcontroller connector.
Expansion Port	J3	15 (DSUB)	Interfaces low voltage power and control signal information to operate an externally connected bipolar monitor device. The control signals interface directly between the microcontroller and the bipolar monitor.
RS-232	J1	9 (DSUB)	Provides external RS-232 communication link between a personal computer and the control board to allow calibrating the LigaSure generator and to provide statistical information about its operating parameters.

Smart Connector Boards

The smart connector boards provide the necessary processing electronics to determine that the correct instruments are attached to the respective LigaSure vessel sealing and bipolar output receptacles. Each output receptacle uses a smart connector board. The board optically reads the attached instrument and generates a 6-bit address code read by the microcontroller to establish a GO_NOGO, green and red smart lamp illumination. A bicolor LED, OPT7, provides the smart indicator status:

- Green lamp indicator accepts the mated instrument. The microcontroller allows RF energy delivery with a footswitch or handswitch request.
- Red lamp indicator shows that the mated instrument is invalid or improperly seated. The microcontroller disables the RF output, prohibiting RF energy delivery with a footswitch or handswitch request.

The smart read process involves optical coupling to the mated instrument plug. Six optical sensors, OPT1 through OPT6, generate the 6-bit smart address code. Each optical sensor incorporates an infrared (IR) emitter and receptor device. The IR devices read the mated plug surface for code identification:

- If the emitter sends an infrared beam to a black area on the plug, the surface reflects minimum light to the receptor. In response, the smart board bit address output sends a high output (+5 V) signal to the microcontroller.
- If the emitter sends an infrared beam to a blue area on the plug, the surface reflects maximum light to the receptor. In this case, the bit address output sends a low, zero volt, level logic signal to the microcontroller.

Comparator devices U2, U5, and U6 provide high discrimination read accuracy of the sensor signals. Signal FET Q1 turns on all six optical devices simultaneously when the microcontroller sends a +5 V signal to the Q1 gate with the BANK 1 command.

All communication to the smart board passes through connector J19. This connector interfaces with the display board, which passes smart connector signals through without processing. Display connector J1 exports the smart connector signal to connector J1 on the microcontroller, which processes the signal for a smart read.

CHAPTER 6

Setup, Tests, and Adjustments

After unpacking or after servicing the LigaSure generator, set it up and verify that it functions correctly.

If the generator does not satisfactorily complete the self-test, calibrate it to ensure its accuracy.

Setting Up the Generator

Warning

Electric Shock Hazard Connect the generator power cord to a properly grounded receptacle. Do not use power plug adapters.

Fire Hazard Do not use extension cords.

Caution

Do not stack equipment on top of the generator or place the generator on top of electrical equipment. These configurations are unstable and/or do not allow adequate cooling.

Provide as much distance as possible between the electrosurgical generator and other electronic equipment (such as monitors). An activated electrosurgical generator may cause interference with them.

Notice

If required by local codes, connect the generator to the hospital equalization connector with an equipotential cable.

Connect the power cord to a wall outlet having the correct voltage. Otherwise product damage may result.

1. Verify the generator is off by pressing the power switch off (O).
2. Place the generator on a stable flat surface, such as a table, platform, or Valleylab cart. Carts with conductive wheels are recommended. For details, refer to the procedures for your institution or to local codes.

   Provide at least four to six inches of space from the sides and top of the generator for cooling. Normally, the top, sides, and rear panel are warm when you use the generator continuously for extended periods of time.
3. According to the procedures used by your institution, connect an equipotential grounding cable to the grounding lug on the rear panel of the generator. Then connect the cable to earth ground.
4. Plug the generator power cord into the rear panel receptacle.
5. Plug the generator power cord into a grounded receptacle.
6. Turn on the generator by pressing the power switch on (|). Verify the following:
   - All visual indicators and displays on the front panel illuminate.
   - Activation tones sound to verify that the speaker is working properly.
7. If the self-test is successful, a tone sounds. Verify that each display shows a power setting of 1 watt, or a yellow bar for seal.

   If the self-test is not successful, an alarm tone sounds. A number may momentarily appear in the bipolar display and, in most cases, the generator shuts down. Note the number and refer to Chapter 7, *Responding to System Alarms*.

Connecting Bipolar or Macrobipolar Accessories

If you plan to use a footswitching bipolar instrument, you must connect a bipolar footswitch. You may also use a footswitch to activate a handswitching instrument.

Warning

Electric Shock Hazard

- Do not connect wet accessories to the generator.
- Ensure that all accessories and adapters are correctly connected and that no metal is exposed.

Caution

Connect accessories to the proper receptacle type.

Connecting the Footswitch

Connect the appropriate footswitch to the corresponding receptacle on the rear panel.

Figure 6-1.
Vessel sealing footswitch receptacle on the rear panel (purple band)

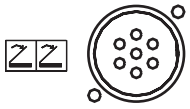
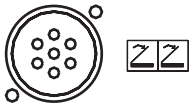


Figure 6-2.
Bipolar/macrobipolar footswitch receptacle on the rear panel (blue band)

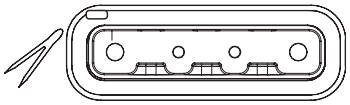


Connecting the Handset

Connect the handset to the proper receptacle on the front panel, using a smart connector adapter as necessary. Verify that the receptacle indicator illuminates green to confirm a proper connection.

Figure 6-3.
Vessel sealing handset receptacle (purple)

Figure 6-4.
Bipolar handset receptacle (blue)



Setting the Output for the Selected Mode

Caution

Set power levels to the lowest setting before testing an accessory.

1. (Optional) To display the previous settings, press the memory button.
2. To set the bipolar mode, connect the handset to the proper receptacle on the front panel, using a smart connector adapter as necessary.

   Verify that the receptacle indicator illuminates green to confirm a proper connection.
3. Set the bipolar or macrobipolar output power or the vessel sealing intensity:
   - To increase the power or intensity, press the Up (Δ) button.
   - To decrease the power or intensity, press the Down (∇) button.

In the bipolar or macrobipolar modes, the power level changes numerically, in one watt increments from 1 to 40, and in five watt increments from 40 to 95.

In the vessel sealing mode, the sealing intensity level changes in one light bar increments, with a range of one to five bars. Increasing the intensity increases the total energy delivered to the tissue for the duration of the seal cycle.

Activating the Surgical Instrument

Notice

Do not activate the generator until the forceps have made contact with the patient. Product damage may occur.

To activate a handswitching instrument, use the controls on the instrument or on the appropriate footswitch. To activate a footswitching instrument, you must use a footswitch.

To reduce the possibility of alternate site burns that may be caused by RF leakage currents, avoid unnecessary and prolonged activation of the generator.

	Handswitching	Footswitching	Activation Indicator
Seal	N/A	Press pedal	Activation tone sounds, Seal indicator illuminates
Bipolar	Close forceps tines firmly	Press pedal	Activation tone sounds, Bipolar indicator illuminates

Periodic Safety Check

Perform the following safety checks every six months to verify that the generator is functioning properly. Record the test results for reference in future tests. If the generator fails to meet any of the checks, refer to Chapter 7, *Troubleshooting*.

Warning

Electric Shock Hazard When taking measurements or troubleshooting the generator, take appropriate precautions, such as using isolated tools and equipment, using the “one hand rule,” etc.

Electric Shock Hazard Do not touch any exposed wiring or conductive surfaces while the generator is disassembled and energized. Never wear a grounding strap when working on an energized generator.

Caution

The generator contains electrostatic-sensitive components. When repairing the generator, work at a static-control workstation. Wear a grounding strap when handling electrostatic-sensitive components, except when working on an energized generator. Handle circuit boards by their nonconducting edges. Use an antistatic container for transport of electrostatic-sensitive components and circuit boards.

Here is a summary of safety checks:

- Inspect the generator and accessories
- Inspect the internal components
- Test the generator
- Confirm outputs
- Check leakage current and ground resistance

Recommended Test Equipment

- Digital voltmeter—Fluke 77 or 87, or equivalent
- True RMS voltmeter—Fluke 8920, or equivalent
- Oscilloscope—Tektronix 2445, or equivalent
- Leakage current tester—Use UL load device or commercially available leakage tester
- Leakage table—per IEC 60601-2-2, Figure 104
- 5, 10, 100, 200, 400, and 1K ohm, all 250 watt, 1% tolerance, noninductive power resistors (Dale NH-250 or equivalent)

Inspecting the Generator and Accessories

Important

When testing RF equipment, follow these test procedures to duplicate manufacturer test data. Lead inductance and stray capacitance can adversely affect readings. Carefully select suitable ground points to avoid ground loop error in measurements.

The accuracy of most RF instruments is approximately 1-5% of full scale. Using uncompensated scope probes causes large errors when measuring high voltage RF waveforms.

Equipment

- Bipolar footswitch and vessel sealing footswitch
- Bipolar adapter
- Bipolar instrument cords
- Vessel sealing instrument cords

Procedure

1. Turn off the generator, and disconnect the power cord from the wall receptacle.

Rear Panel

2. Check the rear panel footswitch receptacles for obstructions or damage. Check for a secure fit by inserting the bipolar footswitch or vessel sealing footswitch connector into the appropriate receptacle.
3. Remove the fuse and verify correct voltage and current rating. Refer to Chapter 4, *Performance Characteristics*.

   If either connection is loose, re-apply the plug to secure the plug/ receptacle mating. If the connection is still loose, try another footswitch for the receptacle. If the connection is still loose, replace the footswitch board assembly. Refer to Chapter 8, *Footswitch Board* for further instructions.

Front Panel

4. Check the bipolar handset receptacle on the front panel for obstructions or damage. You can connect either a footswitching or handswitching bipolar/ macrobipolar instrument to this receptacle. Insert the handset into this receptacle to verify a secure fit.

   If the connection is loose, re-apply the handset to secure the handset/ receptacle mating. If the connection is still loose, try another handset. If the connection is still loose, replace the front panel. Refer to Chapter 8, *Front Panel and Display Board* for further instructions.

5. Check the vessel sealing handset receptacle on the front panel for obstructions or damage. Connect a footswitching vessel sealing instrument to this receptacle, inserting the handset plug firmly into the receptacle to verify a secure fit.

   If the connection is loose, re-apply the handset to secure the handset/receptacle mating. If the connection is loose, try another handset. If the connection is still loose, replace the front panel. Refer to Chapter 8, *Front Panel and Display Board* for further instructions.

6. With the bipolar and vessel sealing handsets properly mated, check that the smart indicator lamp illuminates green. If the smart indicator lamp illuminates red, use the following procedure:

   a. Verify that you have connected the correct LigaSure handset to the seal receptacle.

   b. Verify that the LigaSure handset fits securely in the seal receptacle.

   c. Verify that you have connected a smart bipolar adapter to the bipolar receptacle.

Power Cord

7. Unplug the power cord from the wall receptacle, then remove the cord from the unit.

8. Inspect the power cord for damage.

9. Reconnect the power cord to the generator and wall receptacle.

Inspecting Internal Components

Equipment

- Phillips screwdriver

Caution

The generator contains electrostatic-sensitive components. When repairing the generator, work at a static-control workstation. Wear a grounding strap when handling electrostatic-sensitive components, except when working on an energized generator. Handle circuit boards by their nonconductive edges. Use an antistatic container for transport of electrostatic-sensitive components and circuit boards.

Procedure

To perform the inspection, follow this procedure:

1. Remove the three screws that secure the cover to the chassis. Lift the cover off the chassis. Save the cover and screws for reinstallation.
2. Verify that all connectors are firmly seated.
3. Inspect each board for damaged components, loose or damaged wires, cracks, or corrosion.

   If you find evidence of damage on the control board, display board, high voltage power supply board, smart board, low voltage power supply, or footswitch board, replace the board. Refer to Chapter 8, *Replacement Procedures* for the corresponding replacement instructions.

   If you find evidence of damage on the RF board, replace the board only if the damage is severe. Refer to Chapter 8, *RF Board and Heat Sink* for further instructions.
4. To reinstall the cover, slide the cover onto the chassis from the rear of the unit. Re-install the three screws that secure the cover to the chassis. Refer to Chapter 8, *Cover* for further instructions.

Using the RS-232 Serial Port

The RS-232 serial port allows communication between an attached computer or terminal and the main microcontroller of the generator. This communication link lets you obtain information regarding calibration values, power and mode settings, and the alarm number history of the generator. You can also use the link when testing or calibrating the generator.

Equipment

- Phillips screwdriver

Step 1 – Establish the Communications Link

A. Turn off the generator.

B. On the rear panel of the generator, remove the screws that secure the metal plate that covers the serial port. Set the screws and plate aside for re-installation.

C. Connect a standard DB 9 serial cable to your computer and to the generator serial port.

- Pin 2 is the serial output data line
- Pin 3 is the serial data input line
- Pin 5 is the reference line

D. On your computer, enter your communication program. Configure your computer for 9600 baud, 8 data bits, 1 stop bit, and no parity.

E. Turn on the generator. Your computer displays the following information:

LigaSure Generator

Copyright Valleylab 1998

Master

Master Software Revision: #.##

Feedback Software Revision: #.##

Serial Number: SSSSSSS

Startup Date/Time: MM/DD/YY HR:MN:SC

NOTE: # represents the software version number for the listed microcontrollers. S represents the serial number.

VS_SC = XX

BP_SC = XX

“XX” represents smart connector codes.

Step 2 – Enter Commands

You can enter commands to display data about the generator. Begin each command with a colon (:) and end with a hard return. The # symbol represents a numeric value that you enter with specific commands as noted.

The following table lists the commands you can use:

Command	Action
:PT	Prints Real Time Clock date and time as MM/DD/YY HH:MM
:PSA	Prints the total generator activation time in each mode (Seal, Macrobipolar, and Bipolar) in hours, minutes, and seconds
:PSB	Prints the total number of generator activations in each mode (Seal, Macrobipolar, and Bipolar)
:PSC	Prints the date and time of the latest calibration
:PSE#	Prints the number of times the system has recorded a specific error code # in non-volatile memory
:PSF	Prints the 10 most recent system errors recorded in non-volatile memory Format: Error # MM/DD/YY HH:MM
:PSL	Prints the 10 next most recent system errors (11-20) recorded in non-volatile memory Format: Error # MM/DD/YY HH:MM
:PSK	Prints the total number of generator activations in any mode
:PSO	Prints the total time the generator power has been on, in hours and minutes
:PSP	Prints the average power setting for each mode: Seal, Macrobipolar, and Bipolar
:PSS	Prints the number of activations per side (Seal, Bipolar), by mode, and total
:PSR	Prints the number of regrasps detected
:PM	Prints the generator model name, Master and Feedback software version numbers, and the device serial number
#CAL	Causes the generator to enter the calibration mode

Disconnect the Computer from the Generator

A. Turn off the generator.

B. Disconnect the DB 9 cable from the generator.

C. Position the panel over the serial port and install the screws that secure it to the rear panel of the generator.

Testing the Generator

Turning on the generator initiates an internal self-test to verify the calibration and the operation of the speaker, all indicators, the displays, and some internal components.

Warning

Use the generator only if the self-test has been completed as described. Otherwise, inaccurate power outputs may result.

To test the generator, follow this procedure:

1. Turn on the generator by pressing the front panel On (|) switch. Verify the following:
   - All visual indicators and displays on the front panel illuminate.
   - Activation tones sound to verify that the speaker is working properly.
2. *If the self-test is successful*, a tone sounds. Verify the following:
   - The macrobipolar and bipolar displays each show a power setting of one watt.
   - The seal display shows one amber bar illuminated.

   *If the self-test is **not** successful*, an alarm tone sounds. A number may momentarily appear in the bipolar display and, in most cases, the generator shuts down. Note the number and refer to Chapter 7, *Responding to System Alarms*.

   If you removed and/or replaced the battery, alarm number 105 may appear in the bipolar display when you turn on the generator. If this happens, calibrate the generator.

Confirming Outputs

Use this procedure to ensure the accuracy of the generator. Always confirm the output

- After calibrating the generator

  or

- Every six months

Equipment

- Valleylab smart connector adapter (P/N LS 0500) required to confirm RF output
- Valleylab bipolar forceps cord (E0509)
- Current transformer, Pearson 411
- True RMS voltmeter (such as the Fluke 8920 or equivalent)
- 10, 100, 200, 500, and 1000 ohm 1% noninductive power resistors
- Bipolar footswitch

Checking the Vessel Sealing Output

The LigaSure vessel sealing mode uses a proprietary algorithm that varies the output based on the progress of the sealing action. This algorithm makes a conventional measurement of the output impossible. The seal mode uses the same output circuit and sense circuits as the bipolar mode; therefore, a positive check on the bipolar output also confirms the seal output.

Checking the Bipolar Output

1. Verify that the generator successfully completes the self-test as described in *Testing the Generator.*
2. Establish the communications link as described in *Using the RS-232 Serial Port* in this chapter.
3. Connect the test equipment for bipolar output.
   a. Connect the smart connector adapter to the bipolar instrument receptacle. With the adapter connected, the RS-232 port reads an E4 code.
   b. Connect the bipolar forceps cord to the adapter.
   c. Pass one lead of the cord through the current transformer and connect the current transformer to the voltmeter.
   d. Connect the 100 ohm power resistor across the end of the cord.
   e. Connect the bipolar footswitch to the bipolar footswitch receptacle on the rear panel.
4. Press the bipolar up button (Δ) and set the power to 50 watts.
5. Test the output current for the selected bipolar mode.
   a. Press the footswitch pedal and, while activating the generator, note the output on the voltmeter.
   b. Release the footswitch pedal.
   c. Based on the voltmeter setting and the current transformer you are using, calculate and record the output current.

6. Verify that the generator output is 705 ± 53 mA rms (50 W ± 7.5 W).

   If the output is outside the specified range, calibrate the generator as described in calibration steps 4, 5, 6, and 7. Then repeat this procedure. If the output remains outside the specified range, call the Valleylab Service Center.

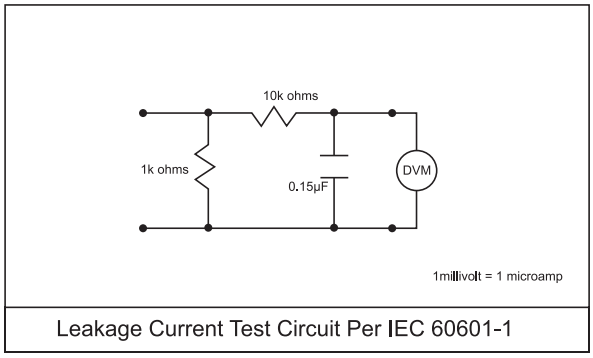
Checking Low Frequency Leakage Current and Ground Resistance

Check the low frequency leakage current and ground resistance before returning the LigaSure generator to clinical use.

Equipment

- DVM
- Leakage current test circuit

Figure 6-1.
The leakage current test circuit per IEC 60601-1



Output Receptacles Source Current

1. Set the DVM to AC volts (200 millivolts [mV]) and connect the leakage current test circuit.
2. Turn on (|) the generator.
3. Measure between all the output receptacles and earth ground. Record the largest reading.
4. Determine the leakage current using the conventional one microamp per one mV.
5. Verify under normal conditions (ground closed, normal polarity) the leakage current is less than 10 microamps (µA). If the leakage current is greater than 10 µA, call the Valleylab Service Center.
6. Verify single fault conditions (ground open) the leakage current is less than or equal to 50 µA. If the leakage current is greater than 50 µA, call the Valleylab Service Center.

Chassis or Earth Leakage

1. Set the DVM to AC volts (200 mV) and connect the leakage current test circuit.
2. Turn on the generator.
3. Measure between the chassis and earth ground.
4. Determine the leakage current using the conventional one microamp (µA) per one mV.
5. Verify under normal conditions (ground closed, normal polarity) the leakage current is less than 100 µA. If the leakage current is greater than 100 µA, call the Valleylab Service Center.
6. Verify single fault conditions (ground open) the leakage current is less than or equal to 500 µA. If the leakage current is greater than 500 µA, call the Valleylab Service Center.

Output Receptacles Sink Current

1. Set the DVM to AC volts (200 millivolts [mV]) and connect the leakage current test circuit.
2. Turn on the generator (110 or 220 Vac) and connect the end of the leakage current test circuit to mains voltage through a 120 kΩ resistor.
3. Connect the other side of the IEC leakage load to all output receptacles.
4. Determine the leakage current using the conventional 1 microamp (µA) per 1 mV.
5. Verify the leakage current is less than or equal to 50 µA. If the leakage current is greater than 50 µA, call the Valleylab Service Center.

Checking High Frequency Leakage Current and Ground Resistance

Check the high frequency leakage current and ground resistance before returning the LigaSure generator to clinical use. Check the leakage current

- After calibrating the generator
- Every six months

Equipment

- 200 ohm, 250 watt, noninductive resistor
- Current transformer
- True RMS voltmeter (Fluke 8920 or equivalent)
- Vessel sealing and bipolar footswitches and bipolar handswitching accessories
- Leakage setup per IEC 60601-2-2, clause 19.101 or 19.102

Checking Seal High Frequency Leakage Current

The LigaSure vessel sealing mode uses a proprietary algorithm that varies the output based on the progress of the sealing action. This algorithm makes a conventional measurement of the RF leakage impossible. The vessel sealing mode uses the same output circuit and sense circuits as the bipolar mode; therefore, a positive check on the bipolar RF leakage also confirms the vessel sealing RF leakage.

Checking Macrobipolar and Bipolar High Frequency Leakage Current

1. Remove the vessel sealing accessories.
2. Connect the 200 ohm load from one side of the bipolar output through the current transformer to the equipotential ground lug on the rear of the generator.
3. Connect the current transformer to the true RMS voltmeter.
4. Connect a bipolar footswitch to the bipolar footswitch receptacle on the rear panel.
5. Activate the footswitch in each mode (macrobipolar and bipolar) at the maximum control setting. Record the leakage current. It should not exceed 69 mA for any mode.
6. If the high frequency leakage exceeds 69 mA, call the Valleylab Service Center for further instructions.

Calibrating the LigaSure Generator

Calibration comprises seven steps. During calibration you verify information specific to the LigaSure generator, adjust the date, and adjust the clock. You also adjust several values, or factors, that ensure the proper operation of the generator.

The following table summarizes the calibration steps and the values you can adjust. Certain values you cannot adjust, but you must verify them.

Notice

After completing any calibration step, follow the instructions displayed on the terminal.

Step	Description	Adjustable?
1	LigaSure Generator Data	
	Generator Model Number	No (verify value)
	Master microcontroller software version	No (verify value)
	Feedback microcontroller software version	No (verify value)
2	Calendar	
	Month	Yes
	Day of the month	Yes
	Year	Yes
3	Clock	
	Hour	Yes
	Minute	Yes
4	Current sense gain factor	Yes
5	Voltage sense gain factor	Yes
6	ECON factor	Yes
7	Save calibration values	Yes

Preparing for Calibration

Equipment

- Bipolar footswitch
- Bipolar adapter and bipolar cable (E0509)
- True RMS voltmeter (Fluke 8920A or equivalent)
- Current transformer (Pearson 411 or equivalent)
- Noninductive power resistors (such as Dale NH-250 with these values: 10, 500, and 1000 ohms)
- Personal computer (PC) with RS-232 cable or terminal capable of RS-232 communication at 9600 baud, 8 data bits, 1 stop bit, and no parity

Before Calibration

1. Before turning on the power, check the CPU battery voltage from TPI (ground) to the body of the battery, and record it.
2. Attach the computer to the generator: Connect a standard DB 9 serial cable to your computer and to the generator serial port.
3. On your computer, enter your communication program. Configure your computer for 9600 baud, 8 data bits, 1 stop bit, and no parity – with no handset connected.
4. Turn the LigaSure generator power on and confirm that a proper serial interface exists by checking the response message from the LigaSure generator.
5. If the battery has been replaced, expect to see error code 105.
6. Keep the serial cable on throughout calibration.

NOTE: If the unit falls out of specification or exhibits alarms during power output tests, complete the calibration procedure.

Step 1 – Verify LigaSure Generator Data

A. From the serial port on the LigaSure generator, establish RS-232 communications as described on page 6-9, then verify LigaSure generator data.

B. Plug a footswitch into the bipolar footswitch connector on the rear panel.

C. Enter the command **#cal**. This should start calibration mode.

D. Press Enter on the terminal to increment the calibration steps. You can pass over any step, but you must perform steps 4 (Isns), 5 (Vsns), and 6 (ECON) in order.

E. Whenever a calibration step calls for keying the generator, press the MACROBIPOLAR (left) pedal on the footswitch.

F. Follow the step instructions shown on the computer monitor.

G. To exit calibration mode, turn off generator power, then turn it back on.

Step 2 – Adjust the Calendar

A. Refer to the following table for the commands to adjust the date.

Month	Day	Year
y: month + 1	u: day + 1	i: year + 1
Y: month + 10	U: day + 10	I: year + 10
b: month - 1	n: day –1	m: year - 1
B: month – 10	N: day - 10	M year - 10

B. When the current date is correct, press Enter to proceed to the next step.

Step 3 – Adjust the Clock

A. Refer to the following table for the commands to adjust the time.

Hour	Minute	Second
y: Hour + 1	u: Minute + 1	i: Second + 1
Y: Hour + 10	U: Minute + 10	I: Second + 10
b: Hour - 1	n: Minute –1	m: Second - 1
B: Hour - 10	N: Minute – 10	M Second - 10

B. When the current time is correct, press Enter to proceed to the next step.

Step 4 – Check and Adjust the Current Sense Gain

A. Follow the instructions on the terminal.

B. Connect a 10 ohm load to the bipolar output jacks, with one side passing through a Pearson 411 current transformer connected to a Fluke 8920A RMS voltmeter.

C. Activate the generator in macrobipolar mode using the rear footswitch receptacle.

D. Referring to the following table for the correct commands, adjust the gain until the meter reads 2.08 A.

I gain
i: gain + 1
I: gain + 10
m: gain - 1
M: gain - 10

Step 5 – Check and Adjust the Voltage Sense Gain

A. Follow the instructions on the terminal.

B. Replace the 10 ohm resistor with a 1000 ohm resistor.

C. Activate the generator in macrobipolar mode using the rear footswitch receptacle.

D. Referring to the following table for the correct commands, adjust the gain until the meter reads 250 mA.

V gain
i: gain + 1
I: gain + 10
m: gain - 1
M: gain - 10

Step 6 – Check and Adjust the ECON Factor

A. Econ Cal Lo, Calibrates High Voltage Control (Lo):

- Activate macrobipolar into a 500 ohm load until value displayed on terminal screen stabilizes within one count.
- This step requires no gain adjustment.

B. Econ Cal Hi, Calibrates High Voltage Control (HI):

- Activate macrobipolar into a 500 ohm load until value displayed on terminal screen stabilizes within one count.
- This step requires no gain adjustment.

Step 7 – Save Calibration Values

A. Enter **S** to save the calibration gain values to non-volatile RAM.

B. This step does not affect the date and time. The system saves these values as soon as you complete the steps in which you adjust them.

CHAPTER 7

Troubleshooting

If the generator is not functioning properly, use the information in this chapter to troubleshoot the system:

- Inspect the generator, connectors and cords, and internal components.
- Identify and correct a malfunction.
- If the system displays an alarm number, take the appropriate action to correct the alarm condition.

Inspecting the Generator

If the generator malfunctions, perform a visual inspection, checking for obvious conditions that may have caused the problem:

- Check the generator for visible signs of physical damage.
- Verify that all accessory cords connect properly.
- Check the power cord. If you find exposed wires, cracks, frayed insulation, or a damaged connector, replace the cord.
- Open the fuse drawer and inspect the fuse housing and fuses for damage and corrosion. Verify that the fuses are firmly seated.

An internal component malfunction in the generator can damage the fuses. You may need to replace the fuses if the generator fails the self-test or stops functioning. Refer to Chapter 8, *Fuses* for further instructions.

Inspecting Receptacles

Equipment

- Bipolar footswitch
- Vessel sealing footswitch
- Bipolar instrument cords (handswitching and footswitching)
- Vessel sealing instrument cords (footswitching)

Procedure

To perform the inspection, follow this procedure:

1. Turn off the generator by pressing the power switch on the front panel to the off position (O).
2. Disconnect the power cord from the wall receptacle.
3. Check the two footswitch receptacles on the rear panel for obstructions or damage. Check for a secure fit by inserting each footswitch connector into the appropriate receptacle.

   If any connection is loose, try another footswitch for the receptacle. If the connection is still loose, replace the footswitch board assembly. Refer to Chapter 8, *Footswitch Board* for further instructions.

4. Check the bipolar handset receptacle on the front panel for obstructions or damage. You can connect either a footswitching or handswitching bipolar/ macrobipolar handset to this receptacle. Insert the handset plug firmly into this receptacle to verify a secure fit.

   If the connection is loose, try another handset. If the connection is still loose, replace the front panel. Refer to Chapter 8, *Front Panel and Display Board* for further instructions.

5. Check the vessel sealing handset receptacle on the front panel for obstructions or damage. Connect a footswitching vessel sealing handset to this receptacle, inserting the plug firmly into the receptacle to verify a secure fit.

   If the connection is loose, try another handset. If the connection is still loose, replace the front panel. Refer to Chapter 8, *Front Panel and Display Board* for further instructions.

6. With the bipolar and vessel sealing handsets properly mated, check that the smart indicator lamp illuminates green. If the smart indicator lamp illuminates red, use the following procedure:

   a. Verify that you have connected the correct LigaSure handset to the seal receptacle.

   b. Verify that the LigaSure handset fits securely in the seal receptacle.

   c. Verify that you have connected a smart bipolar adapter to the bipolar receptacle.

   d. Verify that the smart bipolar adapter fits securely in the bipolar receptacle.

7. If the smart indicator lamp remains red, replace the front panel. Refer to Chapter 8, *Front Panel and Display Board* for further instructions.

Inspecting Internal Components

Equipment

- Phillips screwdriver

Caution

The generator contains electrostatic-sensitive components. When repairing the generator, work at a static-control workstation. Wear a grounding strap when handling electrostatic-sensitive components, except when working on an energized generator. Handle circuit boards by their nonconductive edges. Use an antistatic container for transport of electrostatic-sensitive components and circuit boards.

Procedure

To perform the inspection, follow this procedure:

1. Remove the three screws that secure the cover to the chassis. Lift the cover off the chassis. Save the cover and screws for reinstallation.
2. Verify that all connectors are firmly seated.
3. Inspect each board for damaged components, loose or damaged wires, cracks, or corrosion.

   If you find evidence of damage on the control board, display board, high voltage power supply board, smart board, low voltage power supply, or footswitch board, replace the board. Refer to Chapter 8, *Replacement Procedures* for the corresponding replacement instructions.

   If you find evidence of damage on the RF board, replace the board only if the damage is severe. Refer to Chapter 8, *RF Board and Heat Sink* for further instructions.
4. To reinstall the cover, slide the cover onto the chassis from the rear of the unit. Reinstall the three screws that secure the cover to the chassis. Refer to Chapter 8, *Cover* for further instructions.

Correcting Malfunctions

If a solution to an observed problem is not readily apparent, use the following table to help identify and correct specific malfunctions. After taking action to correct the malfunction, verify that the generator completes the self-test as described in Chapter 6, *Setting Up the Generator*.

NOTE: If you find one or more loose connections, try to reseat the connector. If you find shorts in a component, replace the component.

Situation	Possible Cause	Recommended Action
Generator does not respond when turned on.	Disconnected power cord, faulty wall receptacle, or faulty power cord	Check power cord connections (generator and wall receptacle). Connect the power cord to a functional wall receptacle. If necessary, replace the power cord.
	Loose or disconnected internal cables	Check all internal connections.
	Fuse drawer is open or fuses are blown	Close the fuse drawer. If necessary, replace the fuse(s). For instructions, refer to Chapter 8, *Fuses*. If a problem persists, check the low voltage power supply.
	Faulty power entry module or connections	Check the power entry module and its cable connections.
	Faulty low voltage power supply	Check the low voltage power supply. Replace a faulty supply.
	Damaged control board connectors, malfunctioning control board, or both	Remove the control board and inspect the connectors to the RF board and to the display board for damage, poor seating, etc. If the problem persists, replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.
	Faulty power switch	Replace the power switch. For instructions, refer to Chapter 8, *Power Switch*.
	Malfunctioning front panel components	Replace the front panel assembly. For instructions, refer to Chapter 8, *Front Panel and Display Board*.
	Shorts or disconnects on HV power supply	Check the HV power supply for shorts or disconnects.
	Shorts or disconnects on the RF board	Check the RF board for shorts or disconnects.

Situation	Possible Cause	Recommended Action
Generator is on, but did not complete the self-test.	An alarm condition exists	Check the display for an alarm number. Note the number and refer to *Responding to System Alarms* in this chapter.
	Software malfunction	Turn off, then turn on the generator.
	Loose or disconnected internal cables	Check and correct all internal connections.
	Faulty low voltage power supply	Check the low voltage power supply.
	Damaged control board connectors, malfunctioning control board, or both	Remove the control board and inspect the connectors to the RF board and to the display board for damage, poor seating, etc. If the problem persists, replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.
	Faulty power switch	Replace the power switch. For instructions, refer to Chapter 8, *Front Panel and Display Board*.
	Malfunctioning front panel components	Replace the front panel assembly. For instructions, refer to Chapter 8, *Front Panel and Display Board*.
	Shorts or disconnects on HV power supply	Check the HV power supply for shorts or disconnects.
	Shorts or disconnects on RF board	Check the RF board for shorts or disconnects.
Neither activation tone nor alarm tone sounds; speaker is malfunctioning.	Poor connection or damaged footswitch board ribbon cable	Check/correct connection. If indicated, replace the footswitch board.
	Faulty connections or speaker on footswitch board	Replace the footswitch board. For instructions, refer to Chapter 8, *Footswitch Board*.
	Audio signal malfunction on control board	Replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.

Situation	Possible Cause	Recommended Action
Blank or confusing LED display.	Faulty ribbon cable between control board and display board	Check/connect ribbon cable that connects the display board to the control board.
	Incorrect display information communicated through the control board	Replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.
	Display board malfunction	Replace the display board. For instructions, refer to Chapter 8, *Front Panel and Display Board*.
Buttons do not function correctly when pressed.	Faulty ribbon cable between control board and display board	Check/connect the ribbon cable that connects the display board to the control board.
	Incorrect information communicated through the control board	Replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.
	Faulty ribbon cable between the front panel and the display board	Check/connect the ribbon cable that connects the display board to the front panel.
	Incorrect information is being communicated from the front panel	Replace the front panel. For instructions, refer to Chapter 8, *Front Panel and Display Board*.

Situation	Possible Cause	Recommended Action
Generator is on and accessory is activated, but generator does not deliver output.	Malfunctioning footswitching or handswitching instrument	Turn off the generator. Check and correct all accessory connections. Turn on the generator. Replace the accessory if it continues to malfunction.
	Footswitch connected to wrong receptacle	Move the footswitch connector to the correct receptacle (check the color code).
	Handset connected to wrong receptacle	Move the handset connector to the correct receptacle.
	Power set too low	Increase the power setting.
	An alarm condition exists	Check the display for an alarm number. Note the number and refer to *Responding to System Alarms* in this chapter.
	Blown fuse on power supply	Check the high voltage power supply fuse (F1) and replace if necessary. For instructions, refer to Chapter 8, *Fuses*.
	Control board malfunction	If the system does not illuminate the activation indicator and the tone does not sound, replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.
	RF output stage malfunction (high voltage is present during activation)	Troubleshoot the RF output stage as described below: On the RF board, verify T_ON\ pulses at TP12 during activation. If pulses are not present at U24, pin 1, replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*. Check the power MOSFET at TP11 for failure (typically fail shorted). Check all output relays to verify that they toggle during operation. If they do not, check the relay driver (U12). Check for shorting of the output tuning inductors (L1 and L2). Check the single fault inhibit logic at U20, pin 4 (active low) for correct RF operation.
	Generator does not detect vessel sealing instrument, bipolar instrument, or Smart Connector Adapter	Firmly insert the Smart Connector into the appropriate receptacle on the generator front panel. Ensure the vessel sealing receptacle indicator light changes from red to green.

Situation	Possible Cause	Recommended Action
Footswitch will not activate output.	Malfunctioning or damaged footswitch receptacle	Replace the footswitch board. For instructions, refer to Chapter 8, *Footswitch Board*.
	Footswitch activation signal lost on control board	Replace the control board. For instructions, refer to Chapter 8, *Control Board and Battery*.
	Wrong footswitch type (vessel sealing or bipolar) plugged into footswitch receptacle	Check the color code on the receptacle. Verify that the correct footswitch type is connected.
	Invalid smart code	Check the smart lamp display color. If it is red, re-insert the instrument cable plug and verify proper seating. If the lamp remains red, replace the instrument cable and assembly. If the lamp remains red, replace the front panel. For instructions, refer to Chapter 8, *Front Panel and Display Board*.
Continuous monitor interference.	Faulty chassis-to-ground connections	Check and correct the chassis-to-ground connections for the monitor and, if applicable, for the generator. Check other electrical equipment in the room for defective grounds.
	Electrical equipment grounding connects to different objects rather than a common ground. The generator may respond to the resulting voltage differences between grounded objects	Plug all electrical equipment into line power at the same location.
	Malfunctioning monitor	Replace the monitor.
Interference with other devices only when you activate the generator.	Metal-to-metal sparking	Check all connections to the generator and accessories.
	Electrically inconsistent ground wires in the operating room	Verify that all ground wires are as short as possible and go to the same protective earth grounding source.
	If interference continues when the generator is activated, the monitor is responding to radiated frequencies	Check with the manufacturer of the monitor. Some manufacturers offer RF choke filters for use in monitor leads. The filters reduce interference from activated generators and minimize the potential for an electrosurgical burn at the site of the monitor electrode.

Situation	Possible Cause	Recommended Action
Pacemaker interference.	Intermittent connections or metal-to-metal sparking	Check all connections to the generator. It may be necessary to reprogram the pacemaker.
Abnormal neuromuscular stimulation (stop surgery immediately).	Metal-to-metal sparking	Check all connections to the generator and active electrodes.
	Abnormal 50-60 Hz leakage currents	Inside the generator, carefully inspect for damage that may cause shorting between the AC line voltage and connected patient components.
Smart card reads an invalid handset.	Faulty handset	Replace the handset.
	Handset not valid for this receptacle	Check that you have plugged the handset into the correct receptacle: Vessel sealing handset into vessel sealing receptacle (purple) Bipolar handset into bipolar receptacle (blue).
	Faulty smart card	Replace the front panel. For instructions, refer to Chapter 8, *Front Panel and Display Board*.

Responding to System Alarms

When a system alarm condition exists, an alarm tone sounds and a number flashes in the macro and bipolar displays. Until you correct it, the alarm condition disables the generator, preventing RF activation.

All system alarms require some action on your part to correct the condition. Use the following table to determine how to correct an alarm condition.

After correcting the alarm condition, turn the generator on and verify that no other alarms exist.

Number	Description	Recommended Action
001	FB_UNREPORTABLE_ERROR The master processor has detected an error and directed feedback to transition to the system error state.	Turn the power switch off (O) then on (|) again. If the error reappears, replace the control board.
003	MASTER_DPRAM_TEST_TIMEOUT Master failed to complete DPRAM test in allotted time.	
004	MASTER_CAL_DATA_TIMEOUT Master failed to place calibration data in DPRAM in allotted time.	
005	FB_CAL_CHECK_TIMEOUT Feedback failed to check calibration data in DPRAM in allotted time.	
006	AD_CONVERSION_TIMEOUT Master side A to D conversion failed to complete in the allotted time.	
007	FB_AD_CONVERSION_TIMEOUT Feedback side A to D conversion failed to complete in the allotted time.	
008	MASTER_SETTINGS_TIMEOUT Master failed to write settings into DPRAM within allotted time for feedback microprocessor.	
009	POST_COMPLETE_TIMEOUT Master failed to signal initialization complete within the allotted time.	
010	INVALID_ERROR_CODE_ALARM Invalid error code sent to error handler.	
011	FB_POST_ERRORS There were errors detected in the feedback microprocessor during power on self test (POST), which were already reported to Master microprocessor through fb_init_errors.	
012	FB_INTERNAL_MEMORY_FAULT The main state variable for the feedback microprocessor has been corrupted to an impossible value.	
013	FB_CORRUPTED_STATE_VAR Main feedback state variable has been changed to sys_err incorrectly.	

Number	Description	Recommended Action
014	INVALID_BIP_OPS Invalid value in available operations variable read back from smart connector table.	Turn the power switch off (O) then on (|) again. If the error reappears, replace the control board.
015	INVALID_VS_OPS Invalid value in available operations variable read back from smart connector table.	
016	FB_ILLEGAL_STATE_TRANSITION The combination of the new state requested by the master microprocessor and the current state of the feedback microprocessor represent an illegal state transition request.	
017	FB_ILLEGAL_STATE_VALUE An illegal state value was detected in the feedback state transition checking function.	
018	FB_ILLEGAL_POWER_DEACTIVATIO N_STATE_VALUE An illegal state value was detected in the feedback's power deactivation state machine state variable.	
019	FB_INVALID_MODE_CHANGE An attempt was made to transition directly from one RF output mode to another without first disabling RF (from master)	
020	FB_INVALID_POWER_CHANGE An attempt was made to change power output while SEAL output was activated.	
021	FB_INVALID_MODE_COMMAND RF output mode (function) sent from the master to the feedback was invalid.	
022	FB_INVALID_CAL_DATA Calibration data copied from DPRAM to local RAM has an invalid CRC and is, therefore, unusable.	
023	FB_INVALID_FEEDBACK_MODE Invalid feedback mode state variable value.	
024	MASTER_FPANEL_TEST_ TIMEOUT Master failed to signal feedback that front panel testing has been completed in time.	

Number	Description	Recommended Action
025	FB_EOR_INVALID_OUTPUT_REQUEST Feedback enable_output_relays detected an illegal combination of generator mode and RF output side for output relay configuration.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
026	FB_CAL_OVERVOLTAGE Overvoltage condition discovered during current sensor (Isns) calibration. Make sure the load is as specified in calibration instructions.	Check the loads attached during calibration. It is likely that the attached load has a higher impedance than specified. Correct the attached load. If the error reappears, replace the control board.
027	FB_CAL_OVERCURRENT Overcurrent condition discovered during voltage sensor (Vsns) calibration. Make sure the load is as specified in calibration instructions.	If the error reappears, replace the RF board.
100	INVALID_INIT_ERROR A bad error code was supplied by a powerup self test routine on the master side.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
101	FB_RESET_ERROR Master unable to reset feedback microprocessor at initialization.	
102	WSI_RAM_ERROR ST Microelectronics ST Microelectronics RAM failed test during initialization.	
103	DPRAM_ERROR DPRAM failed test during initialization.	
104	ROM_CRC_ERROR Flash Memory CRC Test of ST Microelectronics Flash Memory failed during initialization.	
105	ALL_CAL_DATA_INVALID Calibration data invalid at powerup, and could not be recovered.	Calibrate the unit. If the error code reappears, replace the battery on the control board. If the error code reappears, replace the control board.
106	CORRECTED_BATRAM_CRC_DATA Battery backed RAM CRC test failed during initialization, but the data was restored from the RTC data.	Reported to serial port only. May indicate a bad battery or failed U3.
107	BATRAM_FAILED_TO_HOLD_CRC_DATA Battery backed RAM CRC test failed during initialization. An attempt to correct the problem failed.	Reported to serial port only. Replace the battery. If the error code reappears, replace the control board (failed U3).

Number	Description	Recommended Action
108	CORRECTED_RTC_CRC_DATA Real time clock RAM CRC test failed during initialization, but the data was restored from battery backed RAM.	Reported to serial port only. Replace the battery. If the error code reappears, replace the control board (failed U1).
109	CORRECTED_BATRAM_CRC_DATA Real time clock RAM CRC test failed during initialization. An attempt to correct the problem failed.	Replace the battery. If the error code reappears, replace the control board.
110	INVALID_RECENT_ERRORS Recent error data kept in battery backed RAM was found to have an invalid CRC at powerup.	Reported to serial port only. Replace the battery. If the error code reappears, replace the control board.
111	INVALID_ERROR_COUNTS Error counts kept in battery backed RAM was found to have an invalid CRC at powerup.	
112	INVALID_LAST_POWER_SETTINGS Last power settings structure in battery backed RAM was found to have an invalid CRC at powerup.	
113	INVALID_STATS_COUNTS Statistical data kept in battery backed RAM was found to have an invalid CRC at powerup	
114	INVALID_MINUTES_ON_WARNING Minutes On data kept in battery backed RAM was found to have an invalid CRC at powerup.	
115	MM_DOSERR_TEST_ERROR Master microprocessor reported a powerup DOSERR test failure.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board. If the error reappears, replace high voltage power supply. If the error reappears, replace RF output FET Q5 on the RF board.
116	DOSERR_TEST_MEMORY_FAULT Doserror test state variable corrupted during powerup dose error test.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
117	MICRO_COMPATIBILITY_ERROR Incompatible software versions on feedback and master processors, or master side software incompatible with digital board type.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
118	DPRAM_RENDEZVOUS_ERROR Master and feedback processors fail to communicate on power up. Either timing or content of communication invalid.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.

Number	Description	Recommended Action
119	INVALID_RTC_VRT_BIT Real time clock reported an erroneous Valid RAM and time bit during initialization.	Turn the power switch off (O) then on again (|). If the error reappears, replace the battery. If the error reappears, replace the control board.
120 **121** **122** **123** **124** **125**	VS_CUT_FOOT_KEY_DOWN VS_MACRO footswitch keying signal is activated during the powerup key test. VS_COAG_KEY_DOWN VS_COAG footswitch/handswitch keying signal is activated during the powerup key test. BIP_CUT_KEY_DOWN BIP_MACRO footswitch/handswitch keying signal is activated during the powerup key test. BIP_COAG_KEY_DOWN BIP_COAG footswitch/handswitch keying signal is activated during the powerup key test. VS_SEAL_FOOT_KEY_DOWN FS_SEAL footswitch keying signal is activated during the powerup key test. VS_CUT_HAND_KEY_DOWN HS_MACRO/SEAL handswitch keying signal is activated during the powerup key test.	Turn the power switch off (O) then on again (|). Do not press buttons or activation devices during power up. If the error reappears, disconnect all footswitches and accessories, then cycle the unit power. If no error appears, then either the footswitch or the accessory is faulty. If the error reappears, turn off the power, disconnect the ribbon cable that connects the footswitch board to the RF board, and turn the power back on. If no error appears, replace the footswitch board. If the error reappears, test the integrity of the ribbon cable attaching the footswitch board to the RF board. If the ribbon cable fails, replace it. If the ribbon cable is good, replace the control board.
126 **127** **128**	MEMORY_BUTTON_DOWN The memory button appeared to be pressed during the powerup key test. SEAL_UP_BUTTON_DOWN The seal power increment button appeared to be pressed during powerup. SEAL_DOWN_BUTTON_DOWN The seal power decrement button appeared to be pressed during powerup.	Turn the power switch off (O) then on again (|). Do not press buttons or activation devices during power up. If the error reappears, turn off the power, disconnect the ribbon cable that connects the front panel buttons to the right side of the display board, and turn the power back on. If no error appears, replace the front panel. If the error reappears, turn off the power, disconnect the ribbon cable that connects the display board to the control board, and turn the power back on. If no error appears, replace the display board. If the error reappears, replace the control board.

Number	Description	Recommended Action
129 **130** **131** **132**	MACRO_UP_BUTTON_DOWN The macrobipolar power increment button appeared to be pressed during powerup. MACRO_DOWN_BUTTON_DOWN The macrobipolar power decrement button appeared pressed during powerup. COAG_UP_BUTTON_DOWN The bipolar power increment button appeared to be pressed during powerup. COAG_DOWN_BUTTON_DOWN The bipolar power decrement button appeared to be pressed during powerup.	Turn the power switch off (O) then on again (|). Do not press buttons or activation devices during power up. If the error reappears, turn off the power, disconnect the ribbon cable that connects the front panel buttons to the right side of the display board, and turn the power back on. If no error appears, replace the front panel. If the error reappears, turn off the power, disconnect the ribbon cable that connects the display board to the control board, and turn the power back on. If no error appears, replace the display board. If the error reappears, replace the control board.
133	ALL_SEAL_DEV_DATA_INVALID On power up, the SEAL parameters in both BATRAM and the RTC are bad. Seal parameters loaded from defaults.	Reported to serial port only. Replace the battery. If the error reappears, replace the control board.
134	MN_FAILED_ATOD_TEST Master processor detected an A/D error during powerup.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board. If the error reappears, replace low voltage power supply.
140 **141**	FB_WSI_RAM_ERROR ST Microelectronics Feedback processor detected an error in external memory during powerup. FB_DPRAM_ERROR Feedback processor detected an error in dual port RAM during powerup.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
142	FB_ROM_CRC_ERROR Flash Memory Feedback processor detected an error in program memory during powerup.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
143 **144**	FB_DPRAM_CAL_DATA_ERROR Feedback processor detected corrupted calibration data during powerup. FB_DOSERR_MEMORY_FAULT Feedback processor detected corrupted memory during dose error circuit test at powerup.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
145	FB_DOSERR_TEST_ERROR Powerup test of DOSERR circuitry failed. Failure detected by feedback processor.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board. If the error reappears, replace the high voltage power supply. If the error reappears, replace the RF output FET Q5 on the RF board.

Number	Description	Recommended Action
146	FB_FAILED_ATOD_TEST Feedback processor detected an A/D error during power up	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board. If the error reappears, replace the low voltage power supply.
162	FB_ECON_OVFLW Feedback calculation of starting ECON overflowed.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
163	MN_MEMORY_CORRUPTED The error disable variables are equal when they should be inverse. mm_errors_enabled == curr_settings.errs_disabled	
164	FB_DOSERR_PWR_OVFLW FB calculation of power overflowed.	Turn the power switch off (O) then on again (|). If the error reappears, re-calibrate the unit. Check sensor lines V_SEN, I_SEN for being too high. If the error reappears, replace the control board. If the error reappears, replace the RF board.
165	MN_DOSERR_PWR_OVFLW MN calculation of power overflowed	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
166	DOSERR_ECON_HV_ERROR Sys_Econ and HV_SNS do not compare within limits during keying.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board. If the error reappears, replace the high voltage power supply board.
167	TON_AVG_ERROR ton_avg reading is too different from calibrated ton_avg value.	Turn the power switch off (O) then on again (|). If the error reappears, calibrate the unit. If the error reappears, replace the control board.
168	TON_AVG_OFF_ERROR ton_avg reading when no RF being output is too different from the average off value which should be read.	
169	FB_MEMORY_CORRUPTED The error disable variables are equal when they should be inverse. fb_errors_enabled == local_curr_settings.errs_disabled	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
170	INVALID_KEY_OUTCOME A bipolar MACRO or bipolar COAG key press resulted in a COMPLETE_FAIL outcome from the feedback processor.	

Number	Description	Recommended Action
172	EXCESSIVE_SYSTEM_VOLTAGE The 5 volt low voltage power supply (U5 P5.4) analog input was greater than 2.5 volts.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
174	INVALID_LAST_MODE_VALUE Invalid mode value detected in last_settings.curr_mode variable by record_keying_event function.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
175	FB_RENDEZVOUS_INVALID_ECHO Data echoed back through dpram by feedback microprocessor did not equal original data stored in master's RAM.	
176	FB_RENDEZVOUS_TIMEOUT Feedback failed to "answer" the settings rendezvous flag within the time allotted.	
177	MNS_ILLEGAL_STATE_VALUE Next_generator_state had a value of RECOVERABLE_ERROR, which is "illegal" in the current context.	
178	MNS_INVALID_STATE_VALUE The next_generator_state had an invalid (undefined) state value that was detected in the routine manage_normal_state.	
179	MRE_INVALID_STATE_VALUE The next_generator_state is a value that is "illegal" in the current context.	
180	ISO_TEST_FAILURE ISO hardware failed, allowing key input to be read as down while ISO test in progress.	Turn the power switch off (O) then on again (|). If error occurs when activating from rear panel, replace the footswitch board. If the error reappears, replace the control board. If error occurs when activating from front panel, check RF board keying circuits (HS_MACRO/SEAL, VS_COAG, BIP_MACRO, BIP_COAG). If the error reappears, replace the control board.

Number	Description	Recommended Action
181	INVALID_KEY_STATE_VALUE process_key_input detected an invalid state value in a key's debounce state variable.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
182	INVALID_OVERALL_KEY_STATE process_key inputs detected an invalid state value in the overall key state variable.	
183	PSB_INVALID_BUTTON_STATE process_simple_button detected an invalid button debounce state value in a button record's debounce state field.	
184	PARB_INVALID_BUTTON_STATE process_auto_repeat_button detected an invalid button debounce state value in a button record's debounce state field.	
185	PBI_INVALID_BUTTON_STATE process_button_inputs detected an invalid button debounce state value in the overall button state variable.	
186	PBI_INTERNAL_MEMORY_FAULT process_button_inputs detected an invalid combination of the overall button state variable, num_key_strokes, and num_buttons_down values: memory has been corrupted.	
187	VKI_INVALID_MODE_DOWN key_capability_match has detected an invalid value in the key_down variable.	
188	VKI_INVALID_KEY_STATE_VALUE validate_key_inputs has detected an invalid key state value in the overall key_state variable.	
189	VKI_INVALID_KEY_DOWN validate_key_inputs has detected an invalid or corrupted key value in key_down.	
190	MBR_INVALID_BUTTON_DOWN Manage button results has detected an invalid or corrupted button identifier in the button_down variable.	

Number	Description	Recommended Action
191	MBR_POWER_SETTINGS_CORRUPTED manage_button_results has detected a corruption of present power settings or recall power settings that indicates memory has been corrupted or MACRO/BIPOLAR powers are greater than 95 watts.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
192		
193	MA_INVALID_AUDIO_STATE manage_audio has detected an invalid state value in the audio state variable.	
194	MA_INVALID_MODE_VALUE manage_audio has detected an invalid mode value in the curr_settings.curr_mode field.	
195	SAT_INVALID_MODE_VALUE select_audio_tone has detected an invalid mode value in the curr_settings.curr_mode field.	
196	MA_AT_INVALID_ALERT_TYPE manage_audio_alert_transition detected an invalid value in the alert type variable current alert.	
197	CCD_CAL_DATA_CORRUPTED check_cal_data detected an invalid CRC in the dual port ram cal store; therefore, dpram cal data has been corrupted.	
198	MAIN_INVALID_STATE_VALUE Main has detected an invalid state value in the current_generator_state variable.	
199	SNESR_INVALID_MESSAGE_TYPE se_exec_normal_serial_result has detected an invalid serial message type stored in the pending_serial_cmd.type field.	
	USL_INVALID_LED_MASK update_smart_leds has detected an invalid parameter (led_mask) value passed to it.	

Number	Description	Recommended Action
214	FB_INIT_ERRORS_TIMEOUT Feedback failed to complete DPRAM test in allotted time.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
215	MM_MAIN_LOOP_DELAY_TIMEOUT Master main loop delay function timer failed to expire.	
216	FB_MAIN_LOOP_DELAY_TIMEOUT Feedback main loop delay function timer failed to expire.	
217	MM_DSP_INVALID_SEAL_POWER display_seal_power has been asked to display an invalid seal watts value.	
218	FB_MODEL_DATA_TIMEOUT Master timed out waiting for hardware signal from feedback that it had placed generator model number and SW rev info into DPRAM.	
219	FPANEL_TEST_TIMEOUT Master front panel test sequence (lamps, LEDs, displays, and tones) did not complete as scheduled.	
220	MCS_ILLEGAL_STATE_VALUE next_generator_state had a value of RECOVERABLE_ERROR, which is “illegal” in the current context.	
221	MCS_INVALID_STATE_VALUE next_generator_state had an invalid (undefined) state value that was detected in manage_calibration_state.	
222	MCS_ILLEGAL_CAL_STATE_VALUE cal_step had an invalid (undefined) state value that was detected in manage_calibration_state.	
223	CAL_ILLEGAL_STATE_VALUE A calibration state machine had an illegal state.	
224	KCM_INVALID_KEY_DOWN key capability match was called with an invalid value in the global key_down variable.	Turn the power switch off (O) then on again (|). If the error reappears, disconnect footswitch connections. If the error reappears, replace the footswitch board. If the error reappears, replace the control board.
225	DOSERR_EXCESS_IDLE_READING More than half scale reading on current or voltage sensor with no keying or RF active.	Turn the power switch off (O) then on again (|). If the error reappears, calibrate the unit. If the error reappears, replace the control board. If the error reappears, replace the RF board.

Number	Description	Recommended Action
226	DOSERR_ECON_RISING sys_econ > 90% of full scale, V_sns and I_sns < 10% of full scale.	Turn the power switch off (O) then on again (|). If the error reappears, calibrate the unit. If the error reappears, replace the control board. If the error reappears, replace the HV supply. If the error reappears, replace the RF board (RF output FET, transformers, etc.).
227 **229** **230**	DOSERR_EXCESS_DIFFERENCE Power computed from master and feedback sensors differs by more than 50 watts. DOSERR_CURRENT_SATURATION Master side current sensor is saturated. DOSERR_VOLTAGE_SATURATION Master side voltage sensor is saturated.	Turn the power switch off (O) then on again (|). If the error reappears, calibrate the unit. If the error reappears, replace the control board. If the error reappears, replace the RF board (Sensors).
231	DOSERR_DESIRED_VAL Master computed desired values differ from feedback computed desired values.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
232	DOSERR_POWER_EXCEEDED Power computed on master side is greater than excess power limit specified by IEC 60601-2-2 3rd Ed.	Turn the power switch off (O) then on again (|). If the error reappears, calibrate the unit. If the error reappears, replace the control board. If the error reappears, replace the RF board (Sensors).
233 **234**	CCD_SEAL_DEV_DATA_CORRUPTED Check cal_seal_dev_data has detected invalid data in the curr_seal_dev data stored in dpram. FB_INVALID_POWER_ACTIVATION_STATE_VALUE Feedback detected an illegal value in the power_activation_state variable.	Turn the power switch off (O) then on again (|). If the error reappears, replace the control board.
451	Over Temperature Error Temperature has risen past the allowable range.	If possible, stop using the unit until it has cooled down. Turn the power switch off (O) then on again (|). If the error reappears, replace the high voltage power supply. If the error reappears, replace the control board.

CHAPTER 8

Replacement Procedures

Follow the procedures in this chapter when you need to replace the following parts:

- High voltage (HV) power supply board
- Control board
- Battery for battery-backed RAM
- Footswitch board
- Low voltage (LV) power supply board
- Front panel
- Display board
- Front panel components, including the power switch
- RF board
- Heat sink
- Power entry module
- Fuses, including two in the fuse drawer, one on the HV power supply, and three on the RF board

These procedures all require that you remove and re-install the generator cover.

Safety

Before performing any replacement procedures, read the following warnings, cautions, and notices.

Warning

Electric Shock Hazard Only trained biomedical engineers and technicians are authorized to service the LigaSure generator.

Electric Shock Hazard To allow stored energy to dissipate after disconnecting power, wait at least five minutes before replacing parts.

Electric Shock Hazard Do not touch any exposed wiring or conductive surfaces while the generator is disassembled and energized. Never wear a grounding strap when working on an energized generator.

Fire Hazard For continued protection against fire hazard, replace fuses only with fuses of the same type and rating as the original fuse.

Caution

The generator contains electrostatic-sensitive components. When repairing the generator, work at a static-control workstation. Wear a grounding strap when handling electrostatic-sensitive components, except when working on an energized generator. Handle circuit boards by their nonconductive edges. Use an antistatic container for transport of electrostatic-sensitive components and circuit boards.

Notice

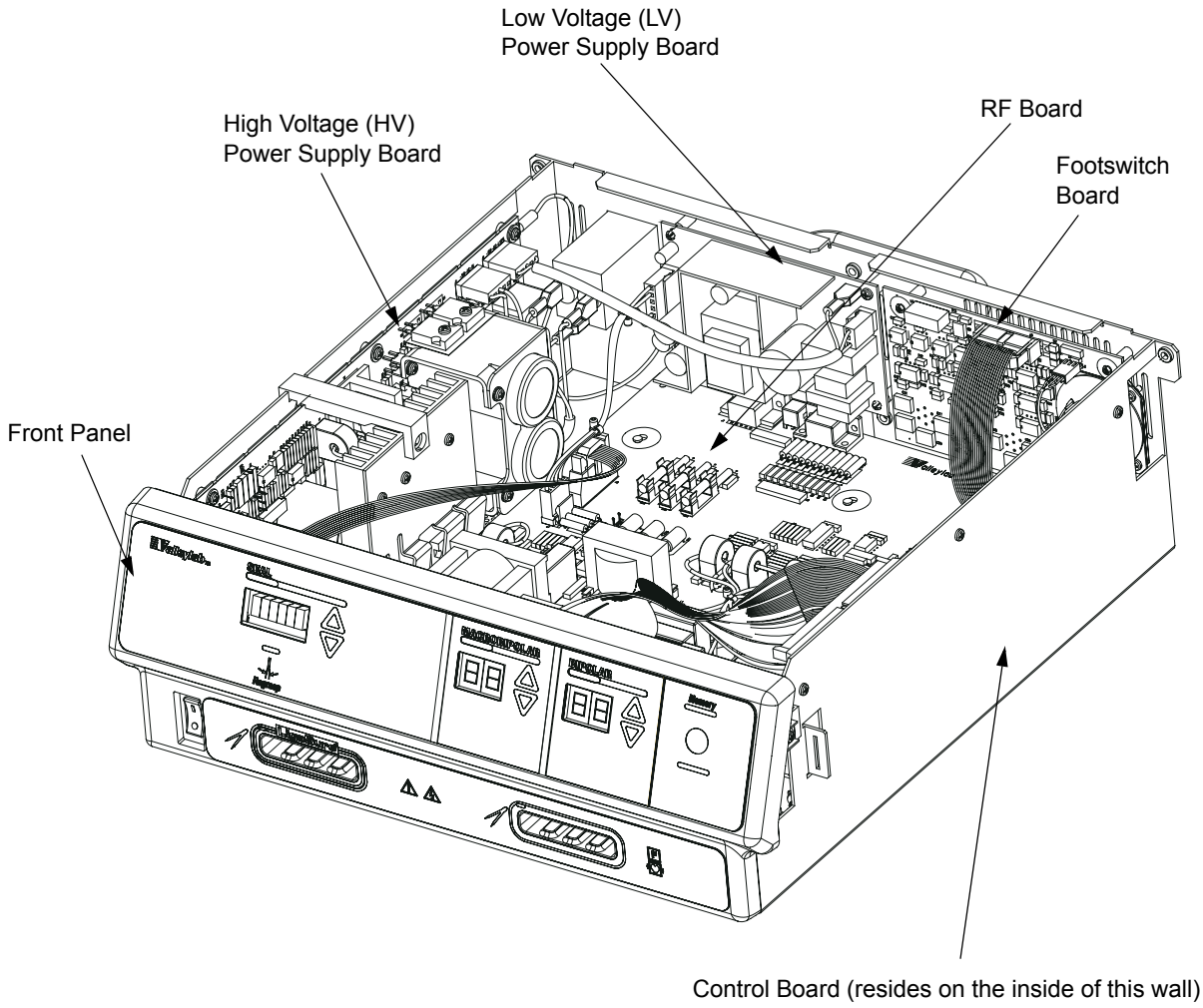
Calibrate the generator after installing a new battery. Internal memory loses calibration values when you remove the battery. Refer to Chapter 6, *Calibrating the LigaSure Generator* for instructions.

Calibrate the generator after you install a new RF board, heat sink, or components on the heat sink. Component differences may affect output waveforms. Refer to Chapter 6, *Calibrating the LigaSure Generator* for instructions.

Map of Major Components

Figure 8-1 identifies the major components in the generator. The map does not show the control board, which resides on the inside of the right wall of the generator.

Figure 8-1.
The location of major components in the generator



Cover

Before you can inspect or replace any component, you must remove the cover. The following procedure describes its removal and re-installation.

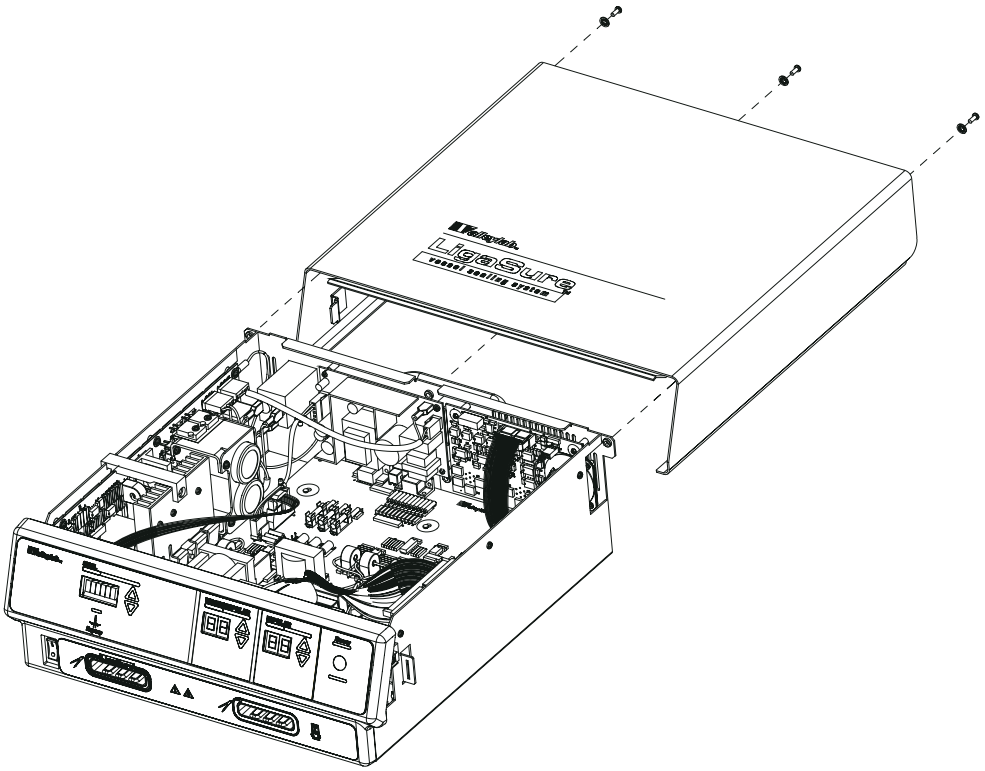
Tools Needed

- Phillips head screwdriver

Remove the Cover

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove three screws (M4 x .7 x 8) that secure the cover to the chassis.
3. Slide the cover toward the rear of the chassis. When the front of the cover catches on the rear of the chassis, lift the cover slightly and continue to slide it toward the rear of the chassis to compete the removal. Set the cover and screws aside for reinstallation.

Figure 8-2.
Removing the cover



Re-install the Cover

1. Slide the cover toward the front of the chassis. When the cover stops sliding forward, lift it slightly and continue to slide it toward the front of the chassis until the leading edge of the cover is tight against the front panel.
2. Replace the three screws (M4 x .7 x 8) that secure the cover to the chassis.
3. Connect the power cord to the wall receptacle. As needed, connect footswitches or handsets to the generator.

High Voltage (HV) Power Supply Board

Removing the HV power supply board involves removing the cover, removing the RF heat sink bracket, disconnecting four cables, removing three screws, and lifting the board out of the chassis. Installing a new power supply reverses the process.

Tools Needed

- Phillips head screwdriver

Remove the High Voltage Power Supply Board

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Remove two screws (M4 x .7 x 8) that secure the RF heat sink bracket to the heat sink and the chassis. Remove the bracket.

4. Remove four cables from the HV power supply board:

Name	Ref*	Location	Wires	Colors
Switched AC power cable	J2	upper rear corner of the board	3	brown, blue, and green/yellow
AC switch #1 cable	J1	next to the first cable	2	brown and blue
HV power supply control ribbon cable	J3	near the front edge of the board	ribbon	red and gray
HV DC cable	J4	under the HV power supply control ribbon cable	4	two black and two red

*All reference points in this table appear on the HV power supply board.

Two latches secure the ribbon cable connector to the HV power supply board. Release them by rotating them away from the connector, then pull the connector away from the board.

5. Remove three screws (M4 x.7 x 8) that secure the HV power supply board to the chassis.

Note that the screw nearest the rear of the unit also fastens the chassis ground to the board by way of a ring tongue terminal.

6. Lift the HV power supply board out of the chassis.

Figure 8-3.
Heat sink bracket and cable connections on the HV power supply board

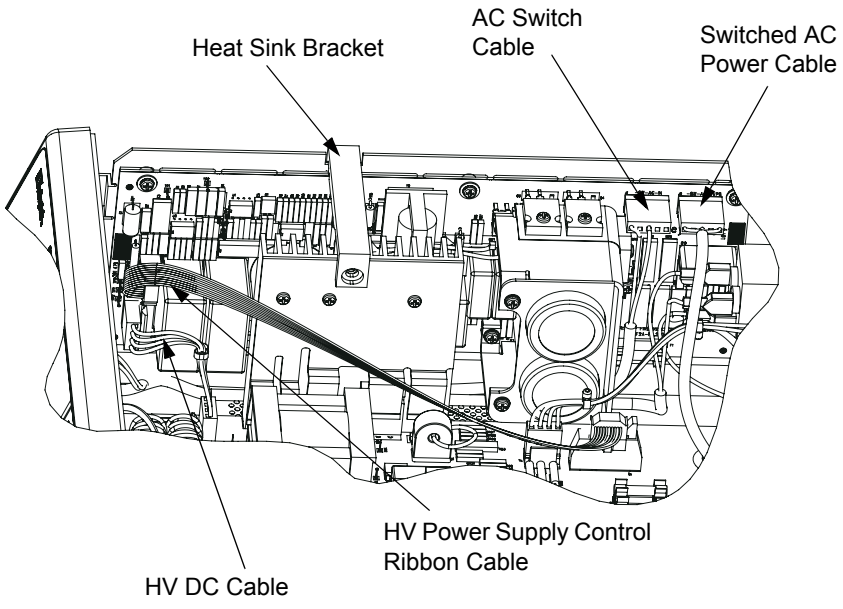
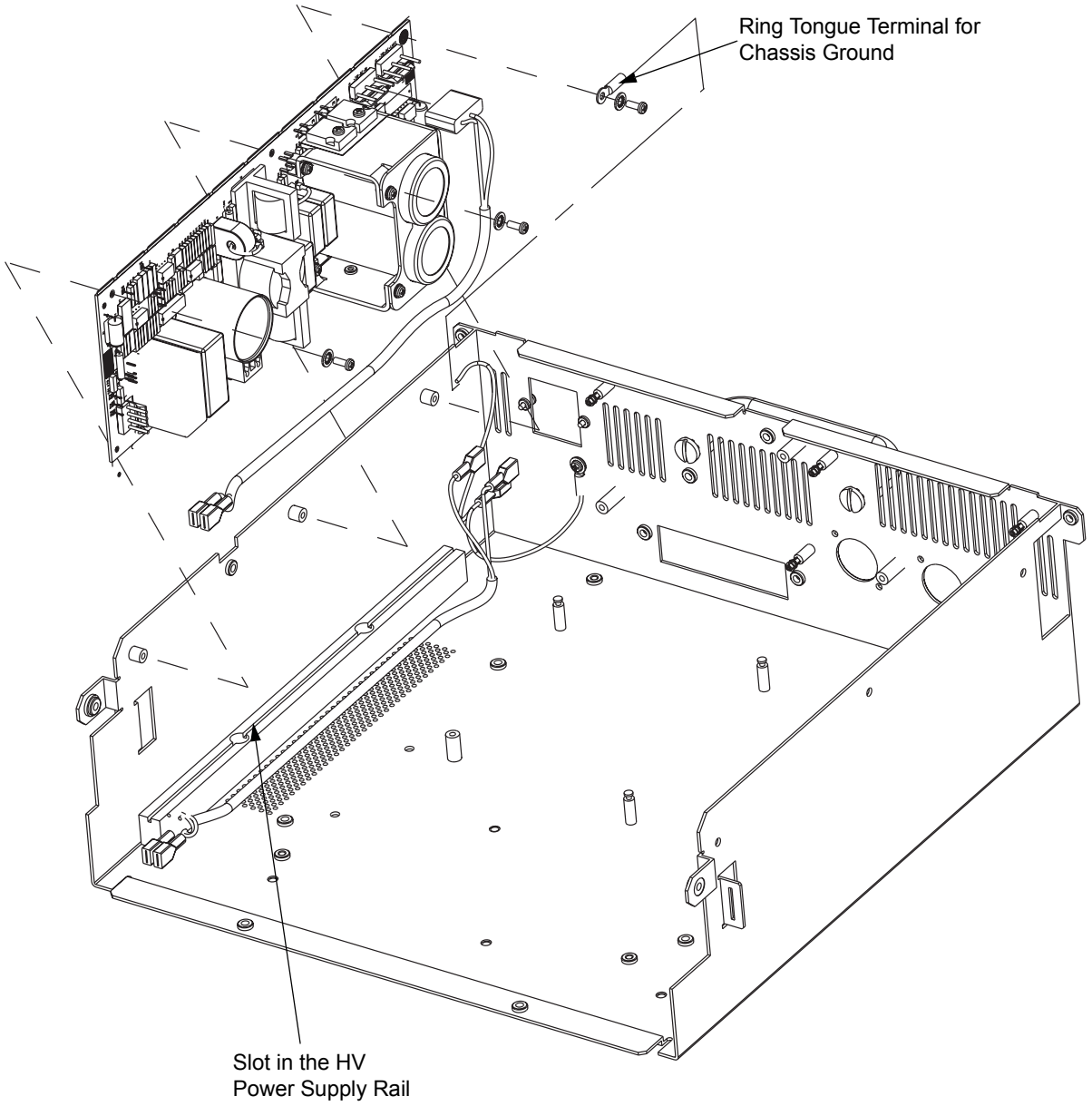


Figure 8-4.
The HV power supply board (front panel and other boards removed from the chassis)



Install a New HV Power Supply Board

1. Orient the board correctly (components with large red caps near the front), then lower it until the bottom edge fits into the slot in the HV power supply rail.
2. Replace the three screws (M4 x .7 x 8) that secure the board to the chassis.

Be sure to reconnect the chassis ground to the screw nearest the rear of the unit, positioning the ring tongue terminal on the screw (component) side of the board.

3. Reconnect four cables to the HV power supply board:

Name	Ref*	Location	Wires	Colors
HV DC cable	J4	under the HV power supply control ribbon cable	4	two black and two red
HV power supply control ribbon cable	J3	near the front edge of the board	ribbon	red and gray
AC switch #1 cable	J1	next to the first cable	2	brown and blue
Switched AC power cable	J2	upper rear corner of the board	3	brown, blue, and green/yellow

*All reference points in this table appear on the HV power supply board.

Two latches secure the ribbon cable connector to the HV power supply board. Be sure they are open before attempting to reconnect the cable. After reconnecting the cable, secure the latches by rotating them toward the connector.

4. Position the RF heat sink bracket on the heat sink and the chassis. Replace the two screws (M4 x .7 x 8) that secure the RF heat sink bracket to the heat sink and the chassis.
5. Replace the cover. For further information, refer to *Cover* in this chapter.
6. Connect the power cord to the wall receptacle.

Control Board and Battery

You may need to replace the battery for the battery-backed random access memory (RAM), the control board, or both. Both procedures involve removing the cover, disconnecting a ribbon cable, removing screws and brackets, and lifting the board out of its connector. Installing a new board reverses the process.

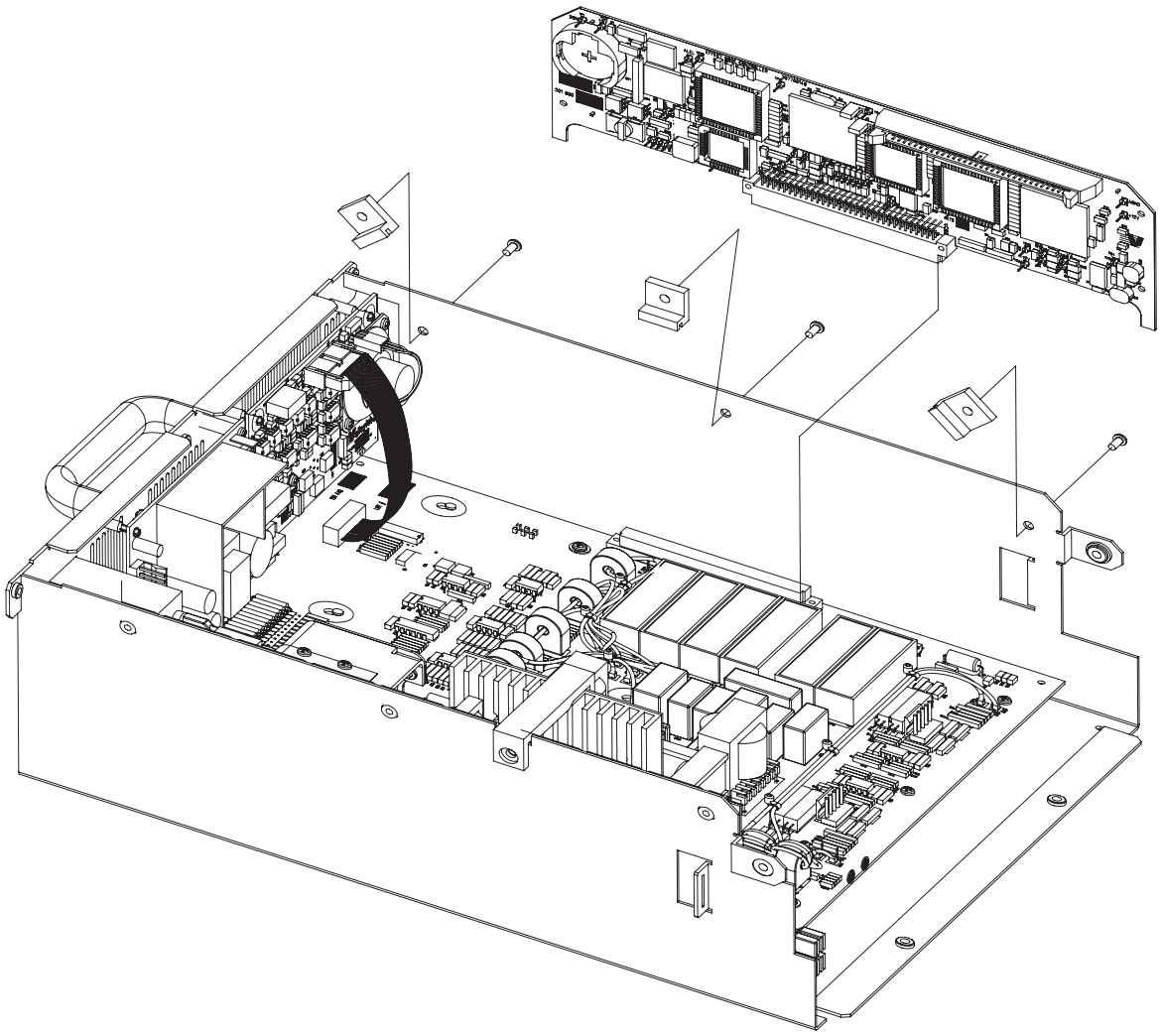
Tools Needed

- Phillips head screwdriver

Remove the Control Board

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Disconnect the display board ribbon cable from the control board:
   a. Unlock the connector on the control board.
   b. Pull the ribbon cable connector out of the receptacle on the control board.
4. Remove three screws (M4 x .7 x 8) that secure mounting brackets to the chassis.
5. Remove the three mounting brackets (one on each upper corner, one in the upper center) that secure the board in place.
6. Carefully slide the control board straight up to disconnect it from the RF board.

Figure 8-5.
Removing the control board from the chassis

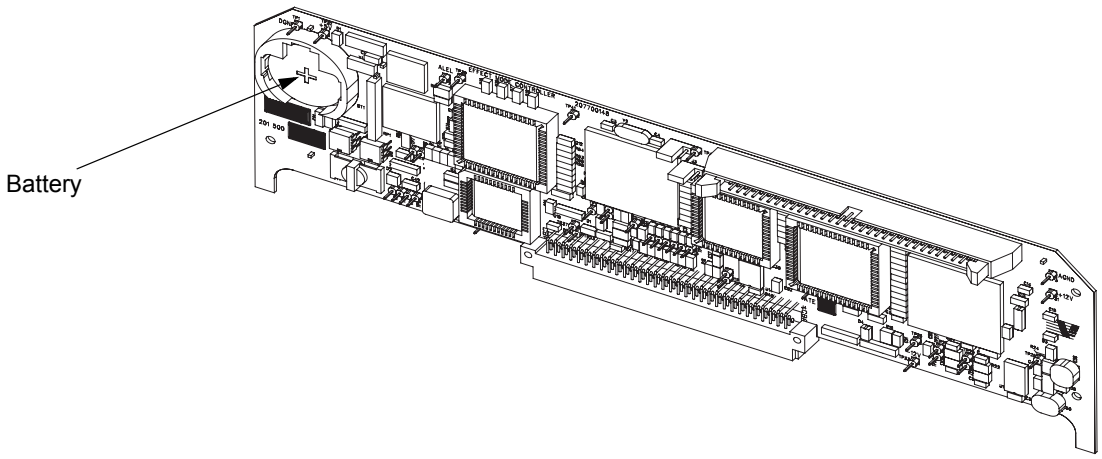


If you need to replace the battery, refer to *Replacing the Battery* in this chapter. If you need to replace the control board, refer to *Control Board and Battery* in this chapter.

Replacing the Battery

The battery resides on the control board. Battery replacement involves removing the cover, removing the control board, then removing the spent battery. Installing the new battery involves reversing the process.

Figure 8-6.
The location of the battery on the control board



Tools Needed

- Phillips head screwdriver

Procedure

Important

Internal memory loses all data when you remove the battery. Therefore, after replacing the battery, you must recalibrate the generator.

When you have removed the control board, if you need to replace the battery, follow this procedure:

1. Grasp the battery and slide it up and out of the socket.
2. Position the new 3 V button cell battery above the socket so that the positive side of the battery is facing out (visible).
3. Slide the battery down into the socket until it is firmly seated.
4. Reinstall the control board. For instructions, refer to *Install the Control Board* in this chapter.

Install the Control Board

Whether you have replaced the battery or the entire board, follow these steps to install the control board:

1. Verify that the packaging for the new control board contains the part number for the LigaSure control board. Do not install any other control board.
2. Install the battery in the battery socket (positive side facing up).
3. Install the control board:
   a. Position the control board over the RF board with the components facing the left panel.
   b. Slide the board down, carefully fitting the edge connector into the matching connector on the RF board.
4. Position the mounting brackets, one on each upper corner and one on the upper center of the board. Replace three screws (M4 x .7 x 8) to secure the mounting brackets and the control board to the chassis.
5. Connect the display board ribbon cable to the control board and lock the connector.
6. Connect the power cord to the wall receptacle. Turn on the generator.
7. Calibrate the generator. Refer to Chapter 6, *Calibrating the LigaSure Generator* for further instructions. If the calibration is successful, go to the next step.
8. Turn off the generator. Disconnect the power cord from the wall receptacle.
9. Install the cover. For further information, refer to *Cover* in this chapter.
10. Connect the power cord to the wall receptacle.

Footswitch Board

This procedure requires removing the cover, disconnecting a cable, removing the control board to gain access to the footswitch board, removing five screws, and lifting the footswitch board out of the chassis. Installing a new footswitch board involves reversing the process.

Tools Needed

- Phillips head screwdriver

Remove the Footswitch Board

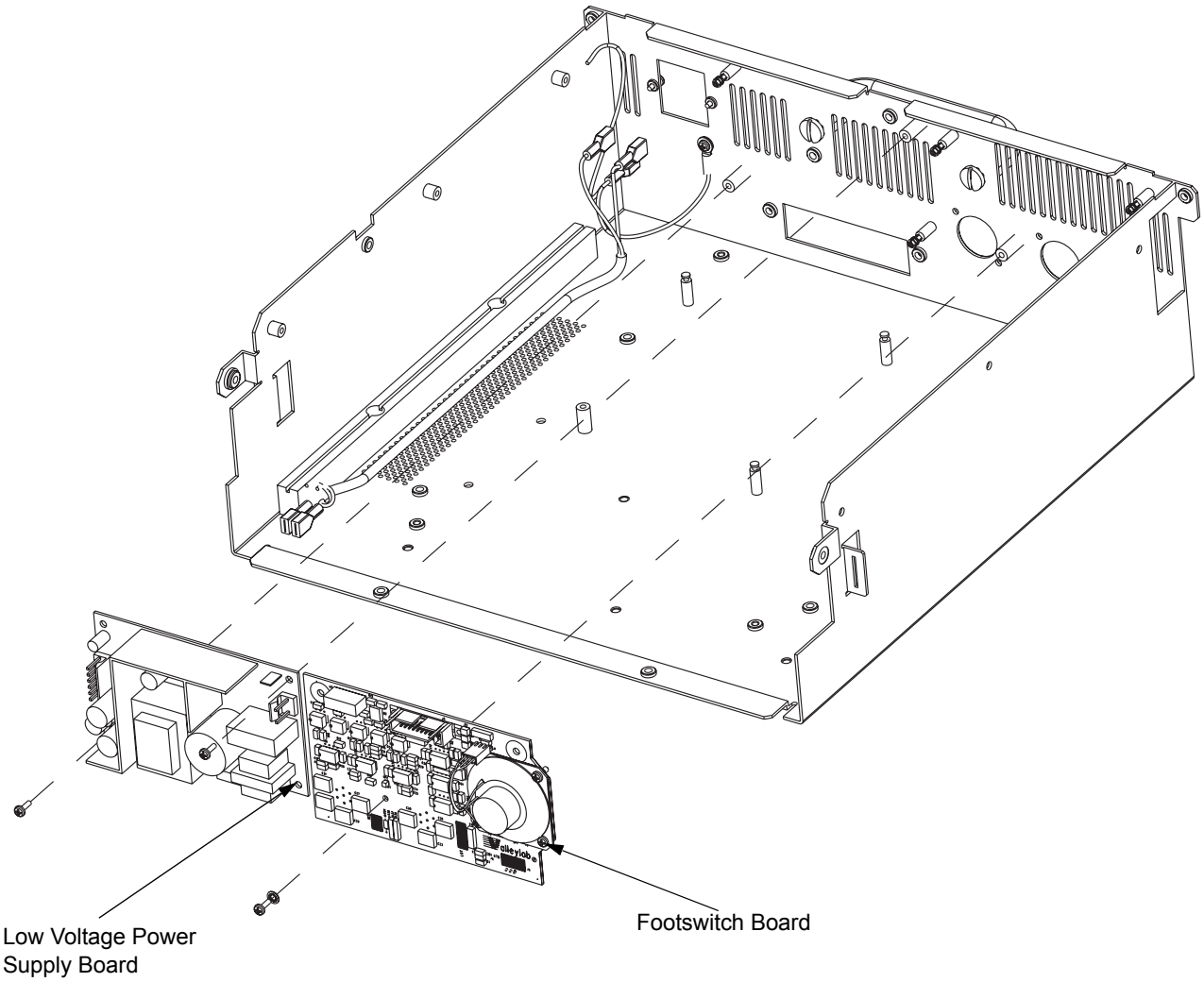
1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Remove the control board. For further information, refer to *Remove the Control Board* in this chapter.
4. Disconnect the footswitch ribbon cable (J3) at both ends:
   a. On the footswitch board, release the latches on the connector, then pull the cable connector out of the connector.
   b. On the RF board, pull the cable out of its connector.
5. Remove five screws (M3 x .5 x 8) and washers that secure the footswitch board to the chassis:
   a. On the outside of the unit, remove the two screws that attach each footswitch connector.
   b. On the inside, remove one screw (just below and to the left of the center of the board) that attaches the board to the chassis.

   DO NOT remove the screws (on the board right end when viewed from the front of the unit) that secure the speaker to the board.
6. Two snap-top standoffs hold the board in position on the chassis. Push the board toward the front of the unit to release it from the standoffs.
7. Lift the footswitch board out of the chassis.

Install a New Footswitch Board

1. Position the footswitch board on the rear wall of the chassis:
   a. Align the footswitch connectors and volume control knob in their holes in the chassis.
   b. Align the holes in the board with the snap-top standoffs.
2. Push the board toward the rear of the unit to snap it onto the standoffs.

Figure 8-7.
The position of the footswitch board on the rear wall of the chassis



3. Replace the screws and washers (M3 x .5 x 8) that secure the board to the chassis:
   a. Install the inside screw and washer first.
   b. Position the footswitch mounting bracket: Hold the bracket in place with a finger in the gap between the board and the rear wall of the unit.
   c. Install the lower left and upper right screws and washers first, then the remaining two screws and washers.
4. Connect the footswitch ribbon cable to the RF board and the footswitch board.
5. Install the control board. For further information, refer to *Install the Control Board* in this chapter.
6. Install the cover. For further information, refer to *Cover* in this chapter.
7. Connect the power cord to the wall receptacle.

Low Voltage (LV) Power Supply Board

Replacing the LV power supply board requires removing the cover, disconnecting two cables, removing two screws, and lifting the board out of the chassis. Installing a new LV power supply reverses the process.

Tools Needed

- Phillips head screwdriver

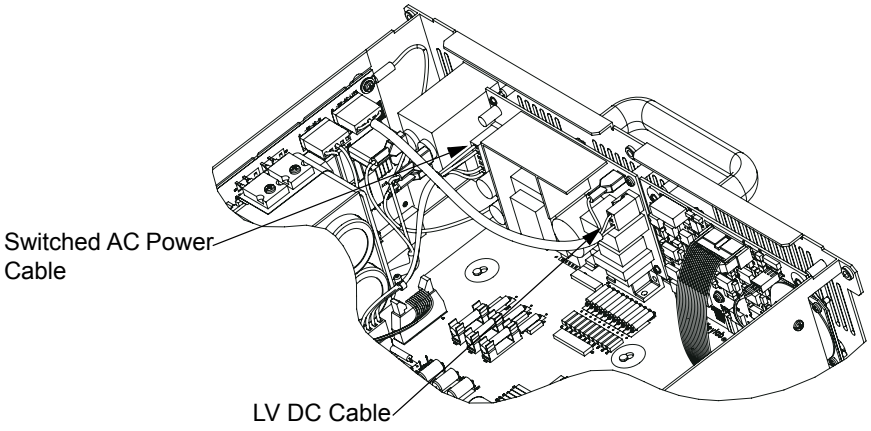
Remove the Low Voltage (LV) Power Supply Board

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Remove two cables from the LV power supply:

Name	Ref*	Location	Wires	Colors
Switched AC power cable	Gnd	upper right corner of the board	1	green/yellow
	J1	upper right corner of the board	2	brown and blue
LV DC cable	J2	left end of the board	4	blue, black, red, and orange

*All reference points in this table appear on the HV power supply board.

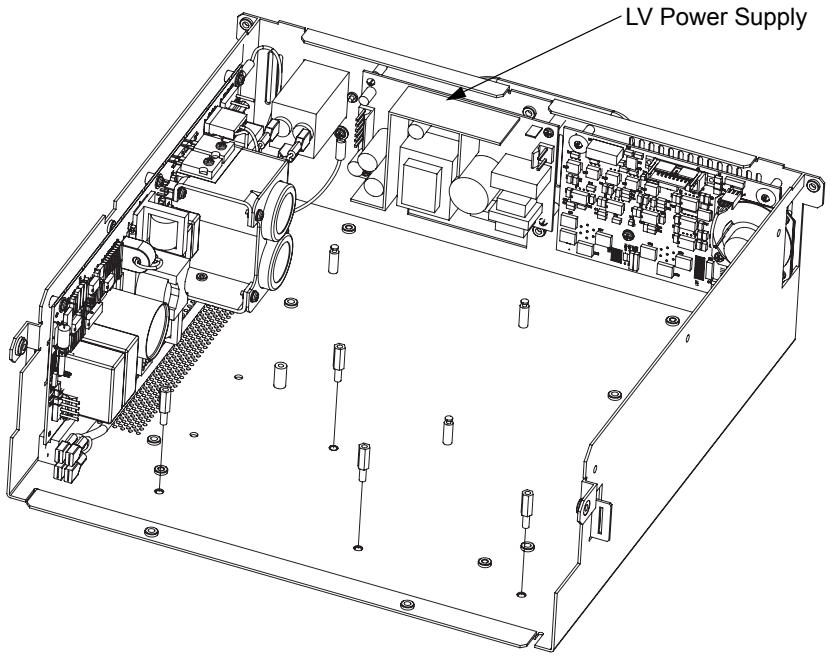
Figure 8-8.
LV power supply cable connections



4. Remove two screws (M4 x .7 x 8, located at the upper right and lower left corners of the board) that secure the board to the chassis.
5. Two snap-top standoffs hold the board in position on the chassis. Push the board toward the front of the unit to release it from the standoffs.

6. Lift the footswitch board out of the chassis.

Figure 8-9.
The LV power supply board in position on the generator rear wall



Install a New LV power supply board

1. Position the LV power supply board on the rear wall of the chassis, aligning the holes in the board with the snap-top standoffs.
2. Push the board toward the rear of the unit to snap it onto the standoffs.
3. Replace the screws (M4 x .7 x 8) that secure the board to the chassis.
4. Reconnect two cables to the LV power supply:

Name	Ref	Location	Wires	Colors
LV DC cable	J2	Left end of the board	4	blue, black, red, and orange
Switched AC power cable	GND	upper right corner of the board	1	green/yellow
	J1	upper right corner of the board	2	brown and blue

5. Install the cover. For further information, refer to *Cover* in this chapter.
6. Connect the power cord to the wall receptacle.

Front Panel and Display Board

You may need to replace either the display board or the entire front panel. Both replacements begin with disconnecting and removing the front panel. Display board replacement then continues with disconnecting and removing the board from the front panel. Installing the display board and front panel reverses the process.

Tools Needed

- Phillips head screwdriver

Remove the front panel

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Disconnect three cables:

Name	Ref	Location	Wires	Colors
Control board ribbon cable		Control board		
RF out cables (2)	J10 & J11 on RF board	Near front edge of RF board	4 (per cable)	brown, blue, yellow, and white

4. Remove four screws (M4 x .7 x 8):
   - Two screws, with washers – one each on the left and right upper corners formed at the front and sides of the unit.
   - Two screws on the underside of the front panel, one under each handset receptacle.
5. Pull the front panel away from the chassis until you gain easy access to the power switch wires. Disconnect the wires:

Name	Location	Pin	No. Wires	Color	From
AC switch 2	Top of switch module	1	1	brown	Input power module
		2	1	blue	
AC switch 1	Bottom of switch module	1A	1	brown	HV power supply board
		2A	1	blue	

Figure 8-10.
Removing the front panel from the chassis

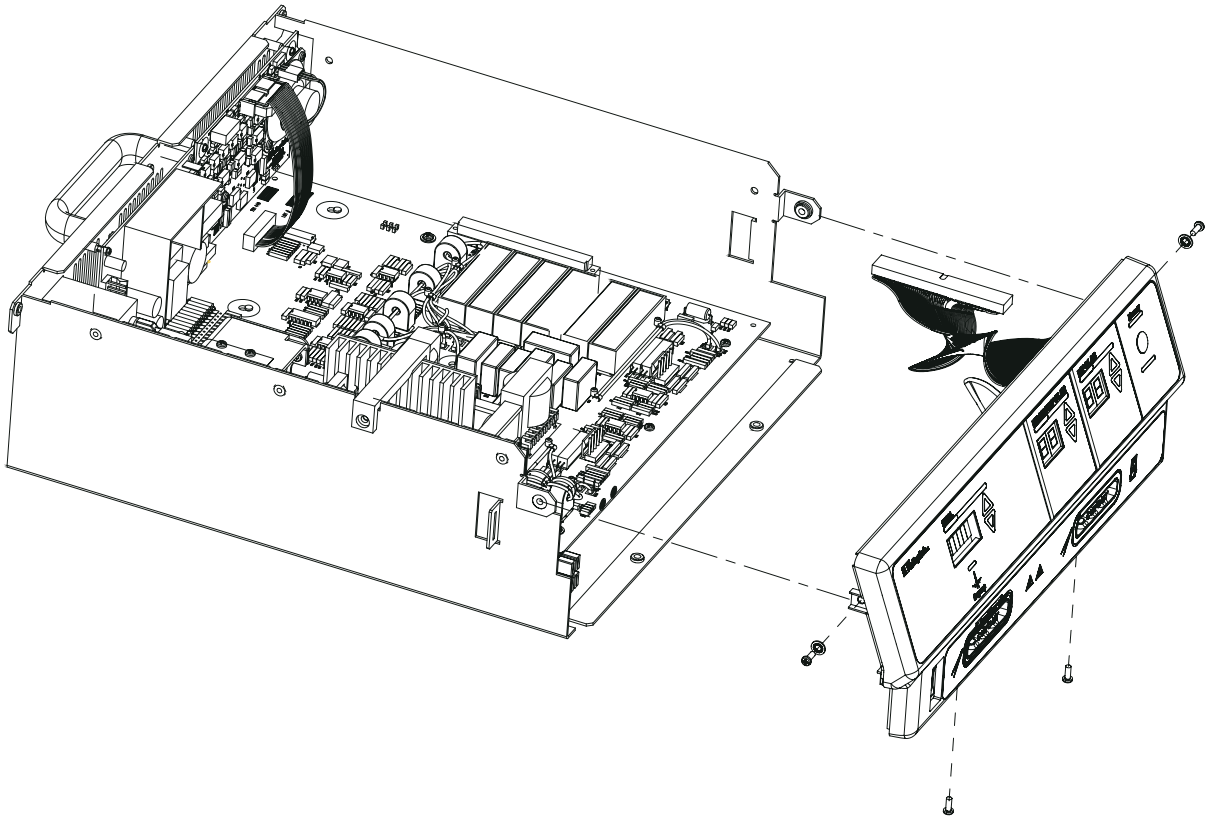


Figure 8-11.
The wires attached to the rear of the power switch

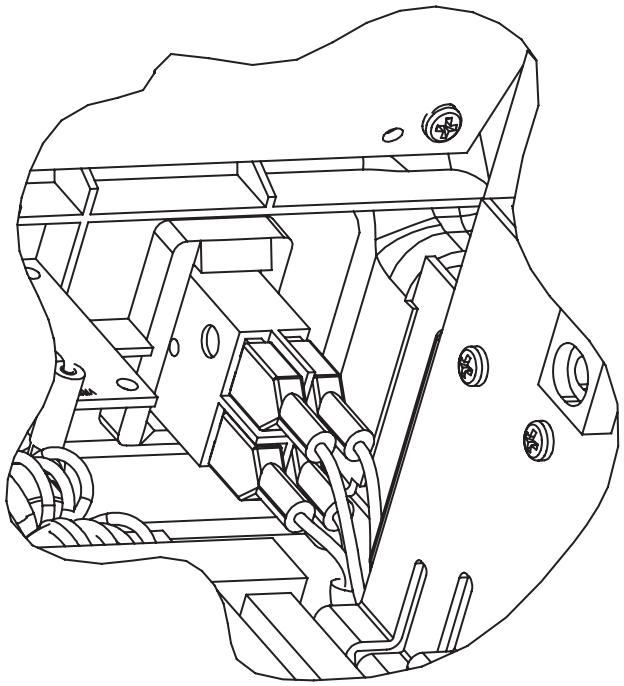
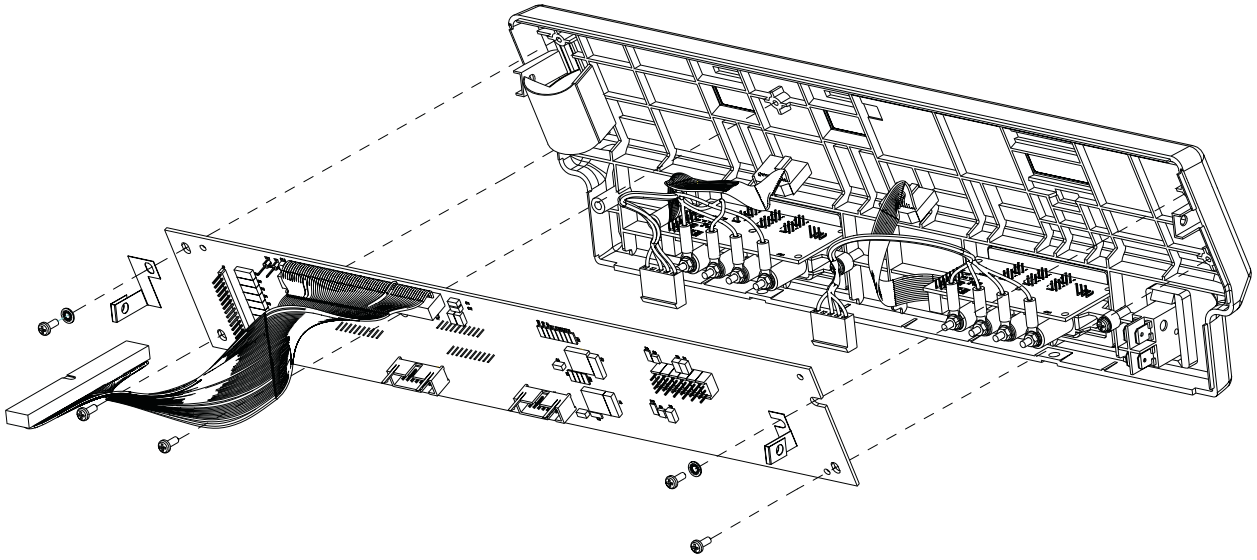


Figure 8-12.
The display board positioned on the front panel



Remove the Display Board

The display board resides in the back of the front panel. Removing the board involves disconnecting three cables, removing five screws, and lifting the board out of the front panel.

1. Disconnect three cables:

Name	Ref	Location	Wires	Colors
Smart I/O cables (2)		RF board		red, gray
Flex ribbon cable	J3 on display board	Near right edge of display board		translucent, with metal traces

Latches hold the smart input/output (I/O) cables in their connectors. To release the cable, rotate the latches away from the connector.

2. Remove five screws (4-20 x 5/16 in. thread forming):

- Two screws on either end of the board.
- One screw immediately under the ribbon cable.

When you remove the two upper corner screws, you also remove left and right display board ground clips. Be sure to put these screws and clips together in a safe place.

3. Lift the display board out of the front panel.

Install the Display Board

1. Move the flex ribbon cable out of the way, then position the display board on the front panel.
2. Replace the five screws that secure the display board to the front panel:

   Replace the lower corner and center screws first.

   Position the display board ground clips, then replace the screws that secure the ground clip and display board on each upper corner.
3. Reconnect three cables:

Name	Ref	Location	Wires	Colors
Flex ribbon cable	J3 on display board	Near right edge of display board		Translucent, with metal traces
Smart I/O cables (2)		RF board		Red, gray

Install the Front Panel

1. Reconnect the wires to the power switch by pushing the terminals onto the pins. Connect the bottom pins, AC switch 1, first.

Name	Location	Pin	No. Wires	Color	From
AC switch 1	Bottom of switch module	1A	1	brown	HV power supply board
		2A	1	blue	
AC switch 2	Top of switch module	1	1	brown	Input power module
		2	1	blue	

2. Position the panel:

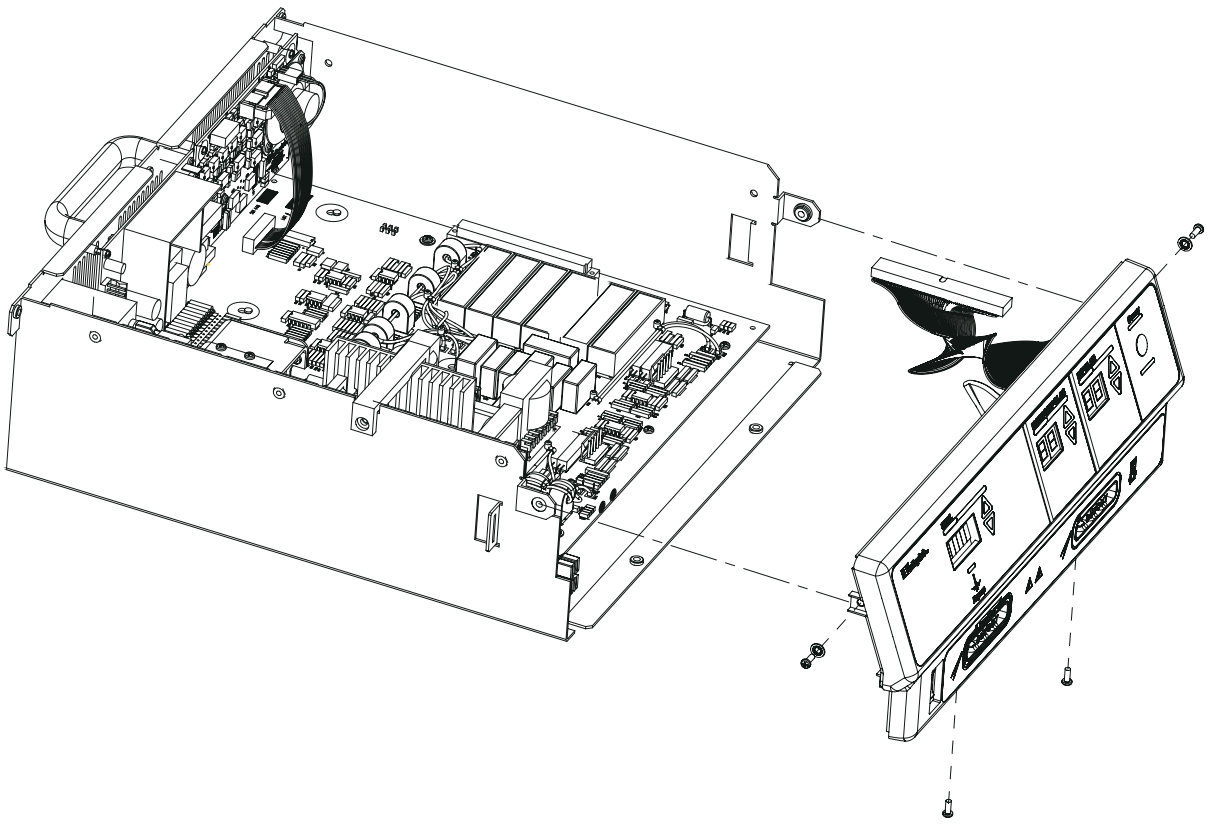
   The lip on the bottom of the chassis fits into the groove on the bottom of the front panel.

   Tabs on the front panel upper corners fit outside the corresponding chassis mounting tabs.
3. Replace the four screws that secure the front panel to the chassis:

   Two screws, with washers – one each on the left and right upper corners formed at the front and sides of the unit.

   Two screws on the underside of the front panel, one under each handset receptacle.

Figure 8-13.
Installing the front panel



4. Reconnect three cables:

Name	Ref	Location	Wires	Colors
RF out cables (2)	J10 & J11 on RF board	Near front edge of RF board	4 (per cable)	brown, blue, yellow, and white
Control board ribbon cable		Control board		

5. Install the cover. For further information, refer to *Cover* in this chapter.

6. Connect the power cord to the wall receptacle.

Power Switch

Replacing the power switch requires removing the cover and the front panel, disconnecting the wires from the back of the power switch, then disconnecting the power switch and taking it out of the front panel. Installing the power switch reverses the process.

Tools Needed

- Phillips head screwdriver

Remove the Power Switch

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Remove the front panel:
   a. Disconnect three cables:

Name	Ref	Location	Wires	Colors
Control board ribbon cable		Control board		
RF out cables (2)	J10 & J11 on RF board	Near front edge of RF board	4 (per cable)	brown, blue, yellow, and white

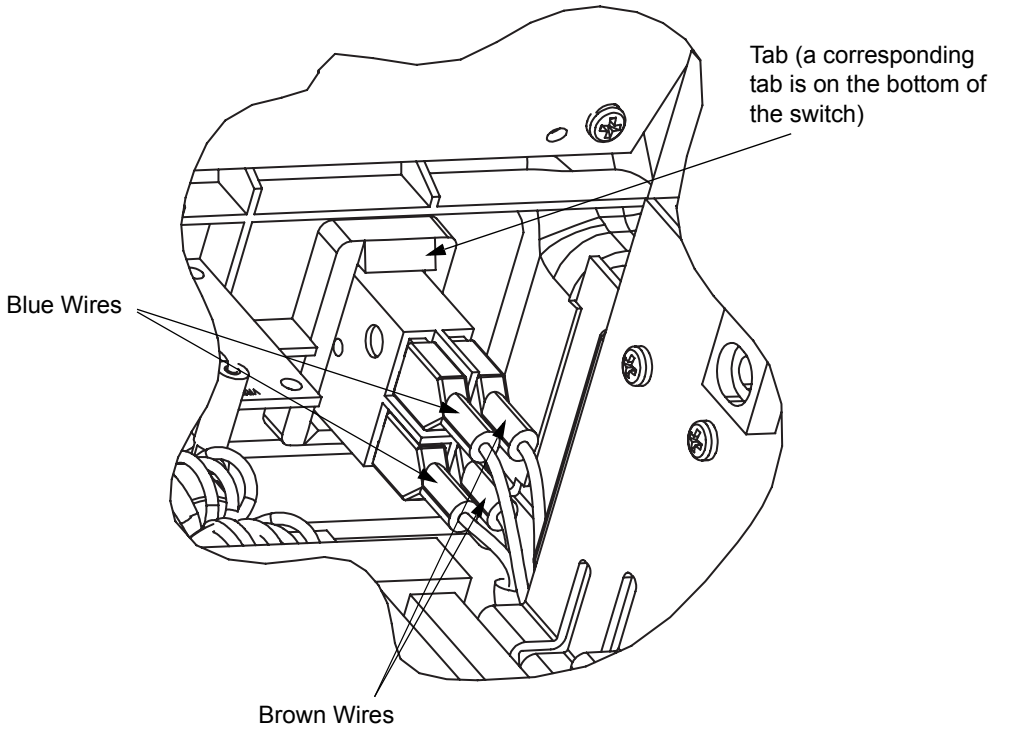
   b. Remove four screws (M4 x .7 x 8):
   c. Two screws, with washers – one each on the left and right upper corners formed at the front and sides of the unit.
   d. Two screws on the underside of the front panel, one under each handset receptacle.

4. Pull the front panel away from the chassis until you gain easy access to the power switch wires. Disconnect the wires:

Name	Location	Pin	No. Wires	Color	From
AC switch 2	Top of switch module	1	1	brown	Input power module
		2	1	blue	
AC switch 1	Bottom of switch module	1A	1	brown	HV power supply board
		2A	1	blue	

1. Remove the switch from the front panel:
   a. At the back of the front panel, press the four tabs on the power switch to release it from the panel.
   b. Push the switch forward to remove it from the panel.

Figure 8-14.
Power switch connections and tabs



Install a New Power Switch

1. Position the power switch in the panel opening so that the on position (|) is above the off position (O).
2. Push the switch into the opening until the switch snaps into place.
3. Reconnect the wires to the power switch by pushing the terminals onto the pins. Connect the bottom pins, AC switch 1, first.

Name	Location	Pin	No. Wires	Color	From
AC switch 1	Bottom of switch module	1A	1	brown	HV power supply board
		2A	1	blue	
AC switch 2	Top of switch module	1	1	brown	Input power module
		2	1	blue	

4. Attach the front panel:
   a. Position the panel:

      The lip on the bottom of the chassis fits into the groove on the bottom of the front panel.

      Tabs on the front panel upper corners fit outside the corresponding chassis mounting tabs.

   b. Replace the four screws that secure the front panel to the chassis:

      Two screws, with washers – one each on the left and right upper corners formed at the front and sides of the unit.

      Two screws on the underside of the front panel, one under each handset receptacle.
5. Reconnect three cables:

Name	Ref	Location	Wires	Colors
RF out cables (2)	J10 & J11 on RF board	Near front edge of RF board	4 (per cable)	brown, blue, yellow, and white
Control board ribbon cable		Control board		

6. Install the cover. For further information, refer to *Cover* in this chapter.
7. Connect the power cord to the wall receptacle.

RF Board and Heat Sink

Removing the RF board involves removing several other components first:

- Cover
- RF heat sink bracket
- Front panel
- Control board
- Cables to RF board
- Screws

Removing the heat sink involves removing the RF board, then the heat sink clip.

Installing the heat sink and RF board reverses the process.

Tools Needed

- Phillips head screwdriver

Remove the RF board

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect any footswitches or handsets currently connected to the generator.
2. Remove the cover.
3. Remove two screws (M4 x .7 x 8) that secure the RF heat sink bracket to the heat sink and the chassis. Remove the bracket.
4. Remove the front panel. For further information, refer to *Front Panel and Display Board* in this chapter.

5. Remove the control board. For further information, refer to *Remove the Control Board* in this chapter.

6. Disconnect several cables:

Name	Ref	Location	Wires	Colors
Footswitch ribbon cable	J3 on foot-switch board	Upper edge of footswitch board	ribbon	
LV power supply cable	J7 on RF board	Near left edge of RF board and in front of LV power supply	4	black, blue, red, and orange
HV power supply ribbon cable	J6 on RF board	Near left edge of RF board and in front of LV power supply	ribbon	red and gray
HV DC cable	J9 on RF board	Near the front left corner of the RF board	4	2 red, 2 black

7. Remove several screws (M4 x .7 x 8):

No.	Type	Location
2	Steel, with washers	Bottom of unit near ventilation vent
2	Steel, with washers	At either end of the control board connector on the RF board
1	Steel, with washers	Near back side of heat sink
1	Steel, with washers	At front left corner of RF board
1	Nylon	In the center of three transformers
2	Nylon	At the center and at the right front of the RF board

8. The RF board rests on four keyhole standoffs.
   a. Slide the board forward to release it from the standoffs
   b. Lift the board about 1/4 inch to clear it from the standoffs.
   c. Pull the board forward to remove it from the chassis.

If you are replacing the heat sink, refer to *Remove the Heat Sink* and *Install the Heat Sink* in this chapter. If you are replacing the entire RF board, refer to *Install the RF Board* in this chapter. Note that, once you have removed the heat sink, you can also replace the HV field effect transistor (FET) at Q5 on the RF board.

Figure 8-15.
Removing the RF board from the chassis

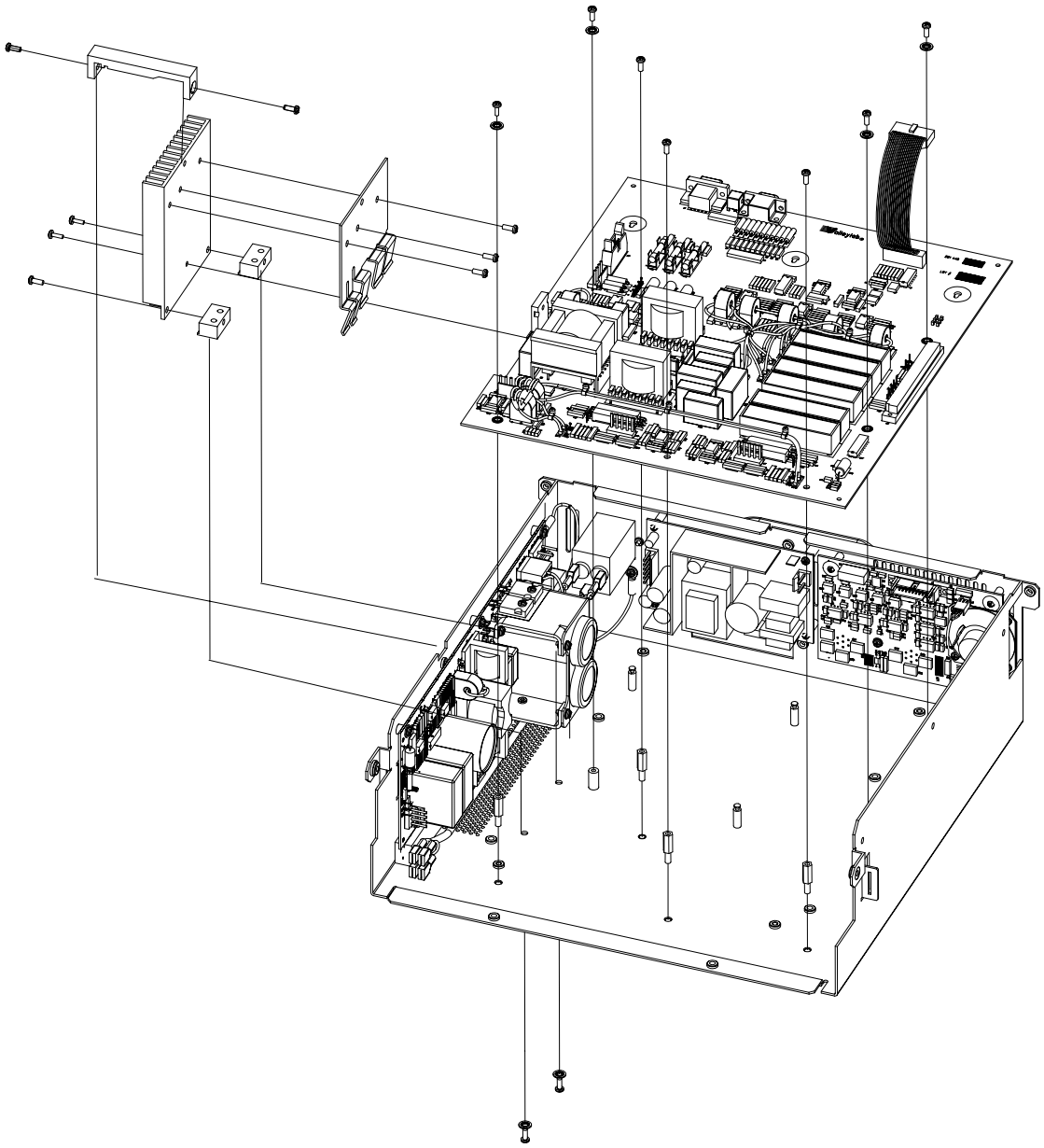
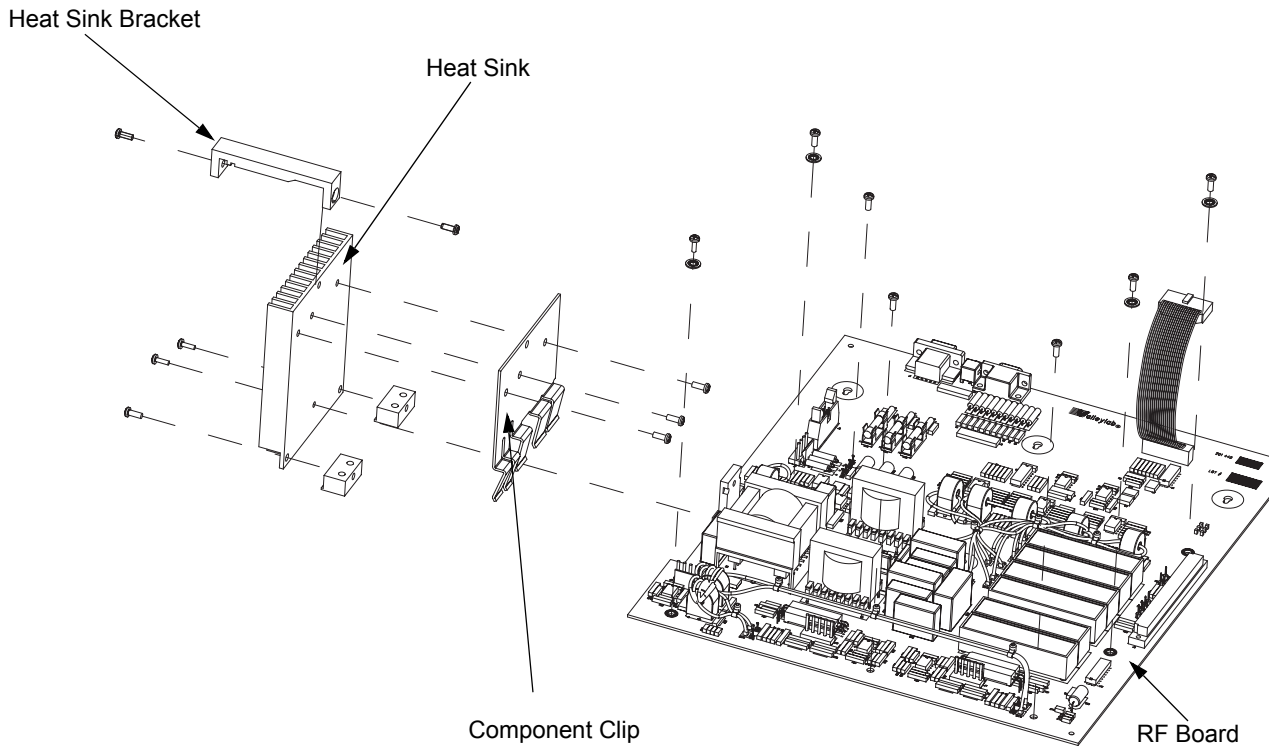


Figure 8-16.
Removing and re-installing the heat sink on the RF board



Remove the Heat Sink

1. Remove three screws (M4 x .7 x 8) located on the RF board side of the heat sink.
2. Remove the component clip from the heat sink.
3. Remove one screw (M3 x .5 x 8) from the bottom center of the heat sink fin side.
4. Remove the heat sink from the RF board.

If you intend to replace the HV field effect transistor (FET) at Q5 on the RF board, do it now. If not, go to the next step.

Install the Heat Sink

1. Position the heat sink on the RF board.
2. Replace the M3 x .5 x 8 screw at the bottom center of the heat sink.
3. Position the component clip on the heat sink.
4. Replace the three screws (M4 x .7 x 8) that secure the component clip to the heat sink.

Install the RF Board

1. Position the board on the keyhole standoffs in the chassis:
   a. Slide the board into the chassis.
   b. Position the board so that its keyhole openings are directly above the keyhole standoffs.
   c. Lower the board so that the bottom of the board rests on the standoff lips (the standoff top reaches through the board keyhole).
   d. Slide the board toward the rear of the chassis until the board is snug on the standoffs.
2. Replace the RF board screws (M4 x .7 x 8):

No.	Type	Location
2	Nylon	At the center and at the right front of the RF board
1	Nylon	In the center of three transformers
1	Steel, with washers	At front left corner of RF board
1	Steel, with washers	Near back side of heat sink
2	Steel, with washers	At either end of the control board connector on the RF board
2	Steel, with washers	Bottom of unit near ventilation vent

3. Reconnect several cables:

Name	Ref	Location	Wires	Colors
HV DC cable	J9 on RF board	Near the front left corner of the RF board	4	2 red, 2 black
HV power supply ribbon cable	J6 on RF board	Near left edge of RF board and in front of LV power supply	ribbon	red and gray
LV power supply cable	J7 on RF board	Near left edge of RF board and in front of LV power supply	4	black, blue, red, and orange
Footswitch ribbon cable	J3 on foot-switch board	Upper edge of footswitch board	ribbon	

4. Install the control board. For further information, refer to *Install the Control Board* in this chapter.

5. Install the front panel. For further information, refer to *Front Panel and Display Board* in this chapter.
6. Position the RF heat sink bracket on the heat sink and the chassis. Replace the two screws (M4 x .7 x 8) that secure the RF heat sink bracket to the heat sink and the chassis.
7. Install the cover. For further information, refer to *Cover* in this chapter.
8. Connect the power cord to the wall receptacle.

Power Entry Module

Replacing the power entry module requires removing the cover, disconnecting cables, removing screws, and lifting the module out of the chassis. Installing a new power entry module reverses the process.

Tools Needed

- Phillips head screwdriver

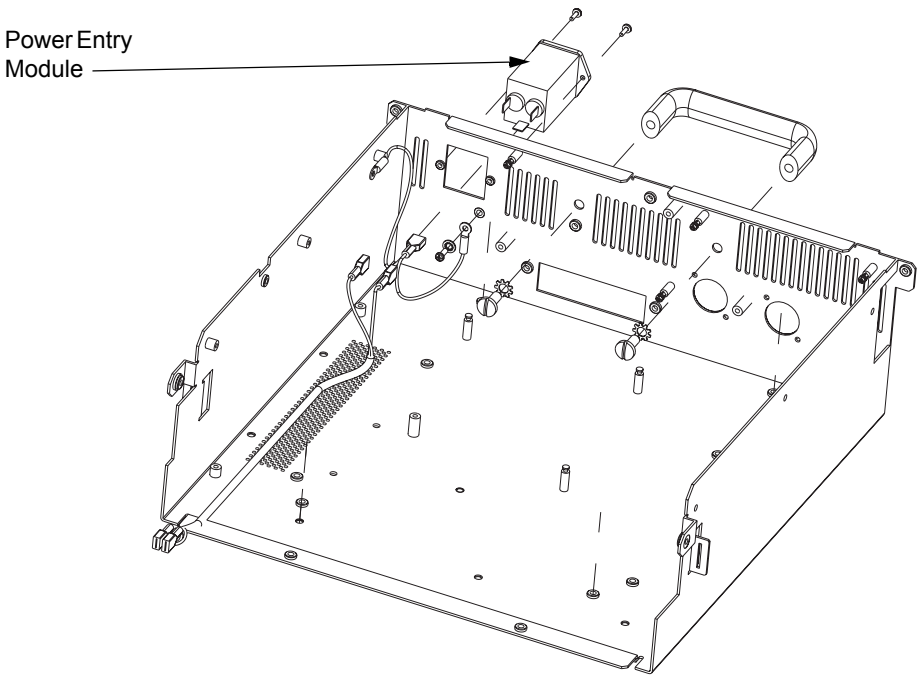
Remove the Power Entry Module

1. Turn off the generator. Disconnect the power cord from the wall receptacle.
2. Disconnect the power cord from the power entry module.
3. Remove the cover.
4. Disconnect three wires:

Name	Location	Wires	Colors
AC switch 2	Pin P, top of rear of module	1	brown
AC switch 2	Pin N, top of rear of module	1	blue
Chassis ground	Center bottom of rear of module	2	green/yellow

5. Remove two screws (M3 x .5 x 8) that secure the power entry module to the rear panel.
6. Slide the module out the rear panel.

Figure 8-17.
Removing the power entry module from the rear of the chassis



Install the Power Entry Module

1. Position the new power entry module at the rear panel opening, then slide the module into place.
2. Replace the screws (M3 x .5 x 8) that secure the module to the rear panel.
3. Reconnect the power entry module wires:

Name	Location	Wires	Colors
Chassis ground	Center bottom of rear of module	2	green/yellow
AC switch 2	Pin N, top of rear of module	1	blue
AC switch 2	Pin P, top of rear of module	1	brown

4. Install the cover. For further information, refer to *Cover* in this chapter.
5. Reconnect the power cord to the rear panel.

Fuses

Fuses reside at three locations in the LigaSure generator:

- Two in the fuse drawer
- Three on the RF board
- One on the HV power supply

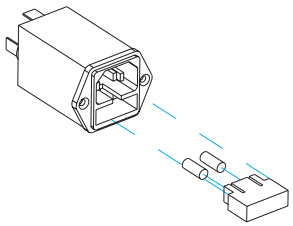
The following procedures tell you how to replace fuses.

Tools Needed

- Phillips head screwdriver
- Small flathead screwdriver
- Fuse puller

Two Fuses in the Fuse Drawer

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect the power cord from the power entry module for easier access to the fuse drawer.
2. To release the fuse drawer, insert a small flathead screwdriver into the slot on the drawer above the power cord receptacle.
3. Slide the drawer out.
4. Pull each blown fuse from the fuse drawer.



5. Replace each blown fuse with one of the same type and rating:

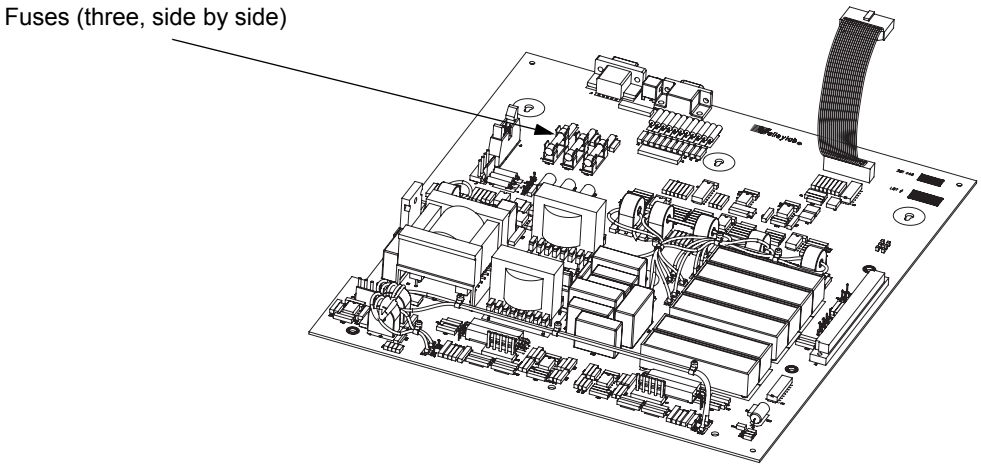
Amps	Volts	Size, in mm	Type
4.0	250	5 x 20	Time delay
4.0	250	5 x 20	Time delay

6. Slide the fuse drawer into its slot until it snaps into place.
7. Connect the power cord to the power cord receptacle.

Three Fuses on the RF Board

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect the power cord from the power entry module.
2. Remove the cover.
3. Locate the fuses at the left rear of the RF board, near the power entry module. Remove any blown fuse.

Figure 8-18.
Three fuses on the RF board



4. Replace each blown fuse with one of the same type and rating:

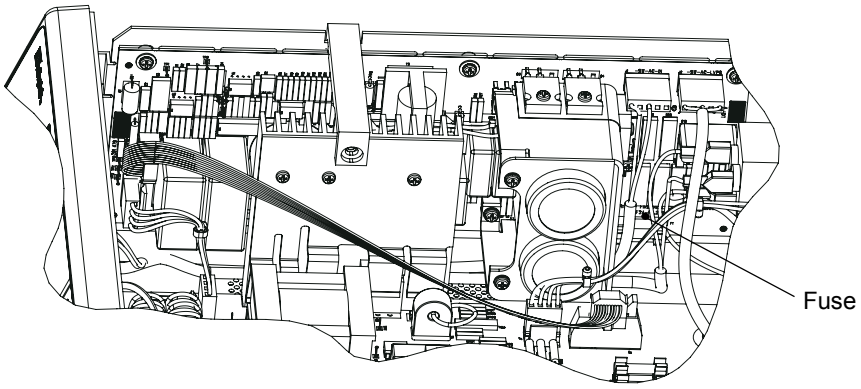
Location	Amps	Volts	Size, in mm	Type
F1	1.0	250	5 x 20	Slo Blo
F2	0.25	250	5 x 20	Time delay
F3	0.25	250	5 x 20	Time delay

5. Install the cover. For further information, refer to *Cover* in this chapter.

One Fuse on the HV Power Supply Board

1. Turn off the generator. Disconnect the power cord from the wall receptacle. Disconnect the power cord from the power entry module.
2. Remove the cover.
3. Remove the HV power supply board. For more information, refer to *High Voltage (HV) Power Supply Board* in this chapter.
4. Locate the fuse at the bottom right corner of the HV power supply board. Remove the blown fuse.

Figure 8-19.
The fuse on the HV power supply board



5. Replace the blown fuse with a new fuse:

   2 A, 250 V, 5 x 20 mm, fast acting

6. Install the HV power supply board. For more information, refer to *High Voltage (HV) Power Supply Board* in this chapter.

7. Install the cover. For further information, refer to *Cover* in this chapter.

8. Connect the power cord to the power entry module and to the wall receptacle.

CHAPTER 9

Repair Policy

This chapter contains the following information:

- The manufacturer's responsibility
- Returning the generator for service
- Returning circuit boards
- Service centers

Responsibility of the Manufacturer

Valleylab is responsible for the safety, reliability, and performance of the generator only under the following circumstances:

- The user has followed the installation and setup procedures in this manual.
- Persons authorized by Valleylab performed assembly operation, readjustments, modifications, or repairs.
- The electrical installation of the relevant room complies with local codes and regulatory requirements, such as the IEC and BSI.
- Equipment use is in accordance with the Valleylab instructions for use.

For warranty information, refer to the Warranty at the end of this guide.

Returning the Generator for Service

Before you return the generator, call your Valleylab Representative for assistance. If instructed to send the generator to Valleylab, first obtain a Return Authorization Number. Then, clean the generator and ship it to Valleylab for service.

Step 1 – Obtain a Return Authorization Number

Call the Valleylab Customer Service Center for your area to obtain a Return Authorization Number. Have the following information ready when you call:

- hospital/clinic name/customer number
- telephone number
- department/address, city, state, and zip code
- model number
- serial number
- description of the problem
- type of repair to be done

Step 2 – Clean the Generator

Warning

Electric Shock Hazard Always turn off and unplug the generator before cleaning.

Notice

Do not clean the generator with abrasive cleaning or disinfectant compounds, solvents, or other materials that could scratch the panels or damage the generator.

A. Turn off the generator, and unplug the power cord from the wall outlet.

B. Thoroughly wipe all surfaces of the generator and power cord with a mild cleaning solution or disinfectant and a damp cloth. Follow the procedures approved by your institution or use a validated infection control procedure. Do not allow fluids to enter the chassis. You cannot sterilize the generator.

Step 3 – Ship the Generator

A. Attach a tag to the generator that includes the Return Authorization Number and the information (hospital, phone number, etc.) listed in "Step 1 – Obtain a Return Authorization Number."

B. Be sure the generator is completely dry before you pack it for shipment. Package it in its original shipping container, if available.

C. Ship the generator, prepaid, to the Valleylab Service Center.

Returning Circuit Boards

Package circuit boards for shipment as follows:

1. Place each circuit board in an electrostatic discharge (ESD) bag or container.
2. Provide a separate packing container for each circuit board.
3. Attach a tag to the container that includes the Return Authorization Number and the information (hospital, phone number, etc.) listed in Step 1-Obtain a Return Authorization Number.
4. Ship the circuit board prepaid to the Valleylab Service Center.

Service Centers

For a complete list of service centers worldwide, please refer to the Valleylab website:

http://www.valleylab.com/valleylab/international/service-world.html

CHAPTER 10

Service Parts

In this chapter:

- Ordering replacement parts
- Replacement parts list

Ordering Replacement Parts

When ordering replacement parts for this system, include this information:

- Model number (located on the rear of the LigaSure generator)
- Serial number (located on the rear of the LigaSure generator)
- Valleylab part number

Replace all components with parts of identical construction and value. Replacement part ratings and tolerances must be equal to, or better than, original. Substituting lower grade parts can adversely affect system performance.

If you have any questions about ordering parts, please call Valleylab Customer Service at 800-255-8522 (within the U.S.).

Map of Major Components

Figures 10-1 and 10-2 identify the major components in the generator.

Figure 10-1.
The location of major components in the generator

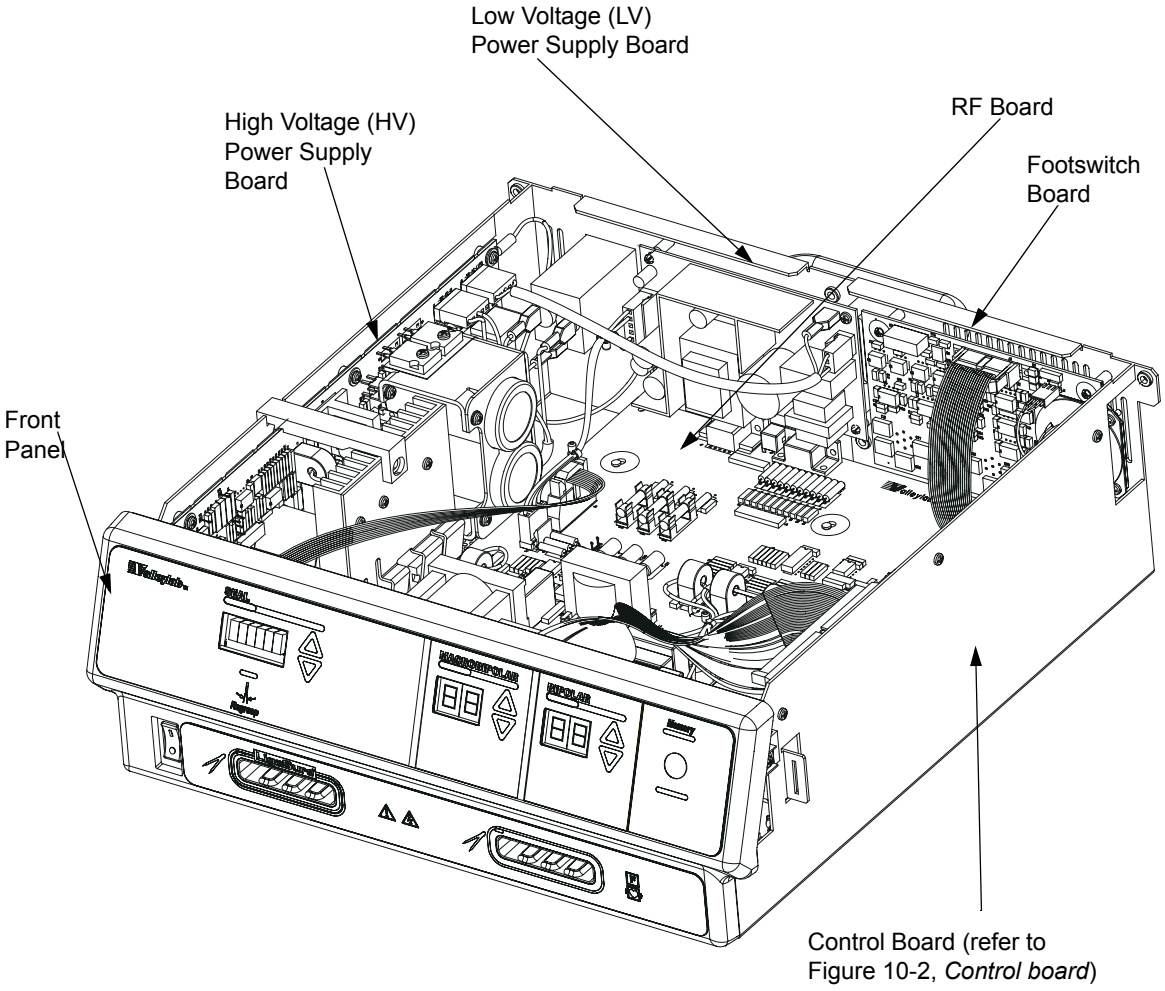
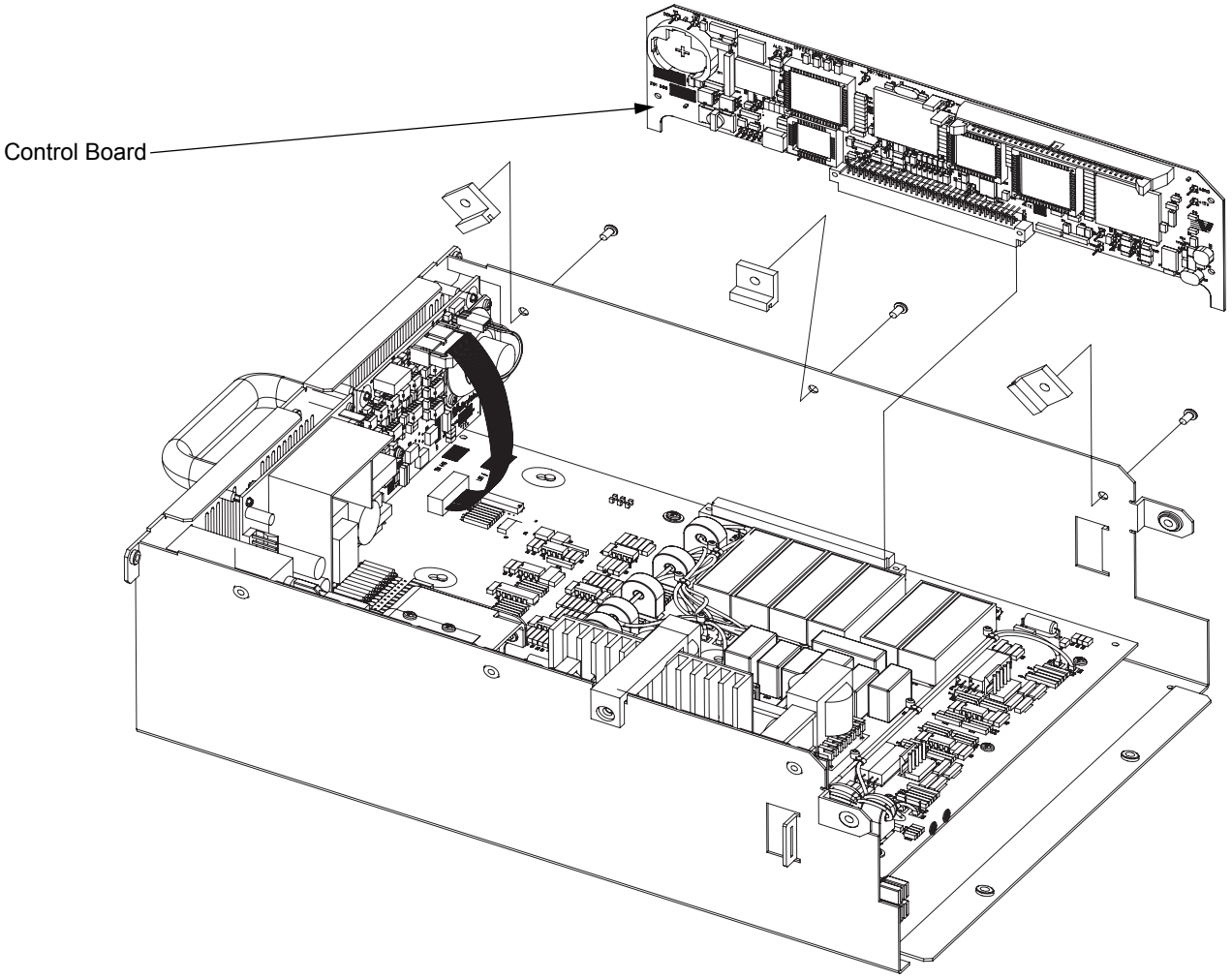


Figure 10-2.
Control board



List of Parts

Assembly, Box

Description
LigaSure bipolar footswitch
LigaSure vessel sealing footswitch
LigaSure User's Guide
LigaSure bipolar adapter
LigaSure Service Manual

Generator Assemblies

Reference Designator	Description	Valleylab Part Number
	LigaSure RF board	210 440 006
	LigaSure footswitch board	201 476 100
	LigaSure high voltage power supply board	201 479 007
	LigaSure control board	1000970
	LigaSure front panel	202 750 192
	LigaSure-8 front panel	202 750 193
	Low voltage power supply board	207 000 185
	LigaSure Powercord, 110 V RT angled, molded	207 002 060
	LigaSure-8 Powercord, 220 V RT angled, molded	207 002 062
	LigaSure HVPS control cable	207 500 600
	LigaSure chassis ground cable	207 500 602
	Low voltage power supply RFSW cable	207 500 210
	AC power switched cable	207 500 609
	AC switch #1 cable	207 500 614
	AC switch #2 cable	207 500 707
	LigaSure HV DC cable	207 500 630
	Fuses, 4A 5 x 20 Slo Blo	215 100 074
	EMI filter	251 400 007
	Cover plate FX	223 301 139

Front Panel Assembly

Reference Designator	Description	Valleylab Part Number
	LigaSure keyboard	207 500 815
	LigaSure RF output cable	207 500 623
	LigaSure display board	207 700 228
	LigaSure Smart Connector	1002033
	LigaSure display board left ground clip	213 130 052
	LigaSure display board right ground clip	213 130 053
	Switch double PDE 120 A Surg	243 025 037

High Voltage Power Supply Board Assembly

Reference Designator	Description	Valleylab Part Number
U2	Max 492CPA op amp IC	210 100 035
U3	(LM 393 N) IC	210 300 011
U4	High speed PWM controller IC	210 720 019
U1	MOSFET Driver 4424 IC	210 800 033
F1	Fuse, 5 x 20 mm	215 100 069
Q1	Transistor FET 2N7000KL	239 200 095
TS1	Transistor voltage suppressor	239 200 056
Q3, Q4, Q5, Q6	FET power IRFP450	239 200 063
CR3	Diode Rect AC bridge RS604	239 700 073
CR8	Diode Rect 120 V, 8 A, ISL9K8120P3	239 700 083
R28, R29	Thermistor Inrush 5 Ohm, 6 Amp	240 003 005
R22	Thermistor, NTC 5%. 1K ROHS	240 003 019
L1	Inductor 500 UHY	251 100 169
T3	Power switching transformer	251 200 077
T2, T4	MOSFET, Gate drive transformer	251 200 079
T1	Inductor, current sense	251 300 007

RF Board Assembly

Reference Designator	Description	Valleylab Part Number
J4	RFSW FSW cable	207 500 612
U13, U3, U9	Timer NE555N IC	210 006 000
U1, U2	74HCOO IC	210 230 007
U10, U11	MOSFET driver 4451 IC	210 250 101
U14, U15, U4, U7	(LM 393 N) IC	210 300 011
U8	Dual comparator IC	210 300 111
U5, U6	AD827 dual op amp IC	210 400 023
U12	2803A IC	210 800 002
F1	Fuse, 5 x 20 mm, 1 A, slow, UL CS	215 100 075
F2, F3	Fuse, 5 x 20 mm, 0.25 A, Slo Blo	215 100 083
K1	12 V Relay	230 013 000
RL1, RL2, RL3, RL4, RL 5, RL6	COTO-9442 Relay	230 017 003
Q1, Q2, Q3, Q4	FET VN10KM transistor	239 200 095
Q6	FET Signal power 240 V TN2404KL	239 200 097
TS1, TS2, TS3	Voltage suppressor transistor	239 200 056
Q5	FET HV N-CH transistor	239 200 073
OPT1, OPT 2, OPT3, OPT4	Single PCB mounted opto-isolator	239 750 073
L1, L2	Choke RF VSG	251 100 168
T1, T2, T3, T4, T5, T6, T8, T9	Inductor, current sense	251300 007
T7	RF transformer	251 300 035

Control Board Assembly

Reference Designator	Description	Valleylab Part Number
	LigaSure PCB effect mode control assembly	1000970
U9	T-On ASIC programmed IC	210 730 250
	3 V battery	250 020 028

CHAPTER 11

Warranty

Valleylab, a division of Tyco Healthcare Group LP, warrants each product manufactured by it to be free from defects in material and workmanship under normal use and service for the period(s) set forth below. Valleylab's obligation under this warranty is limited to the repair or replacement, at its sole option, of any product, or part thereof, which has been returned to it or its Distributor within the applicable time period shown below after delivery of the product to the original purchaser, and which examination discloses, to Valleylab's satisfaction, that the product is defective. This warranty does not apply to any product, or part thereof, which has been repaired or altered outside Valleylab's factory in a way so as, in Valleylab's judgment, to affect its stability or reliability, or which has been subjected to misuse, neglect, or accident.

The warranty periods for Valleylab products are as follows:

Electrosurgical generators or argon units:	One year from date of shipment
Mounting fixtures (all models):	One year from date of shipment
Footswitches (all models):	One year from date of shipment
Patient return electrodes:	Shelf life only as stated on packaging
Sterile single use items:	Sterility only as stated on packaging

This warranty is in lieu of all other warranties, express or implied, including without limitation, the warranties of merchantability and fitness for a particular purpose, and of all other obligations or liabilities on the part of Valleylab. Valleylab neither assumes nor authorizes any other person to assume for it any other liability in connection with the sale or use of any of Valleylab's products.

Notwithstanding any other provision herein or in any other document or communication, Valleylab's liability with respect to this agreement and products sold hereunder shall be limited to the aggregate purchase price for the goods sold by Valleylab to the customer. There are no warranties which extend beyond the terms hereof. Valleylab disclaims any liability hereunder or elsewhere in connection with the sale of this product, for indirect or consequential damages.

This warranty and the rights and obligations hereunder shall be construed under and governed by the laws of the State of Colorado, USA. The sole forum for resolving disputes arising under or relating in any way to this warranty is the District Court of the County of Boulder, State of Colorado, USA.

Valleylab, its dealers, and representatives reserve the right to make changes in equipment built and/or sold by them at any time without incurring any obligation to make the same or similar changes on equipment previously built and/or sold by them.

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The **LigaSure™ Vessel Sealing Generator Service Manual** consists of two parts - the text (part 1 of 2) and this Schematics Supplement (part 2 of 2) which contains the schematics.

Valleylab Part Number: 1018246

Valleylab™
Innovations That Work

tyco Healthcare

Valleylab
a division of Tyco Healthcare Group LP
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Boulder, Colorado 80301-3299

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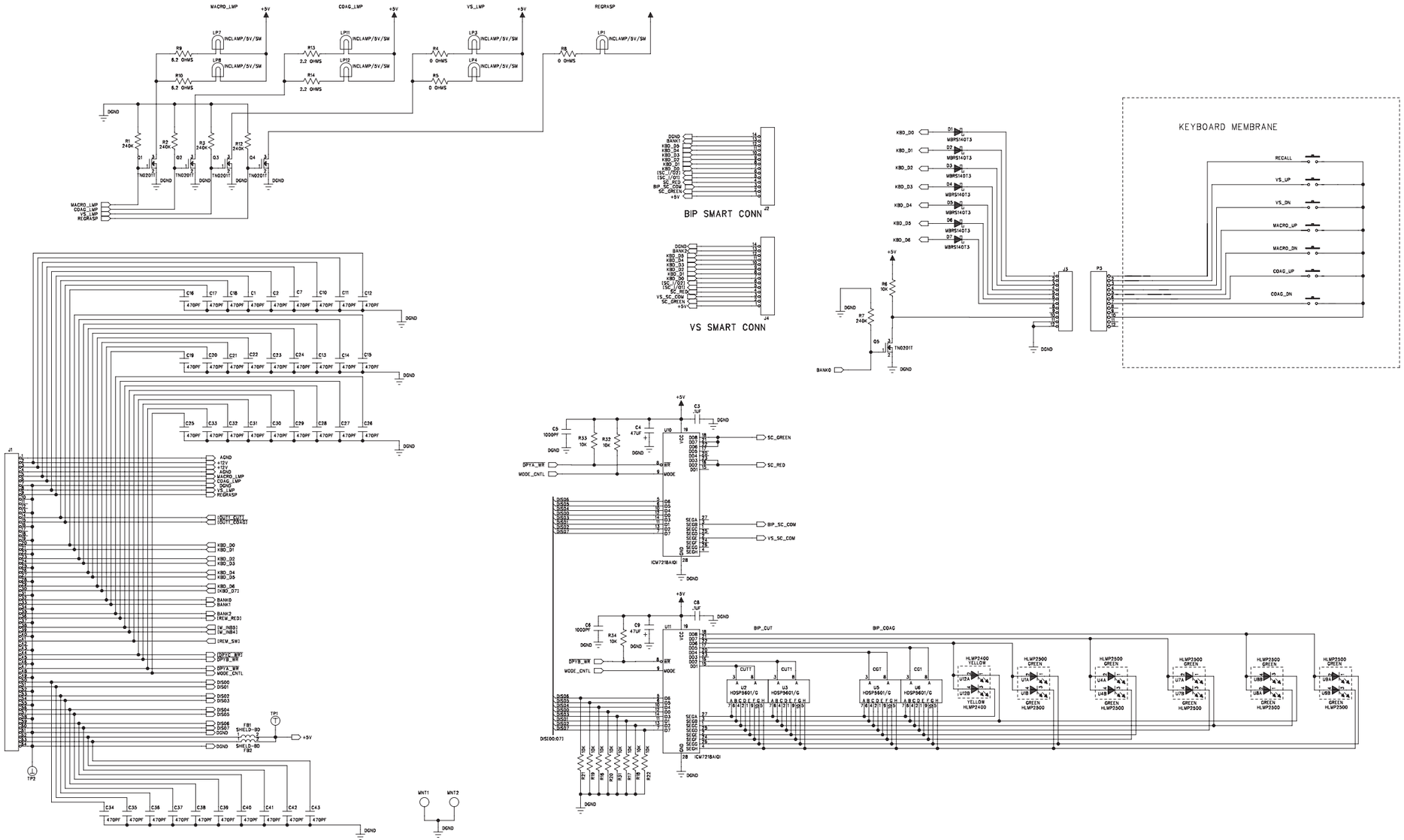
Schematics Supplement

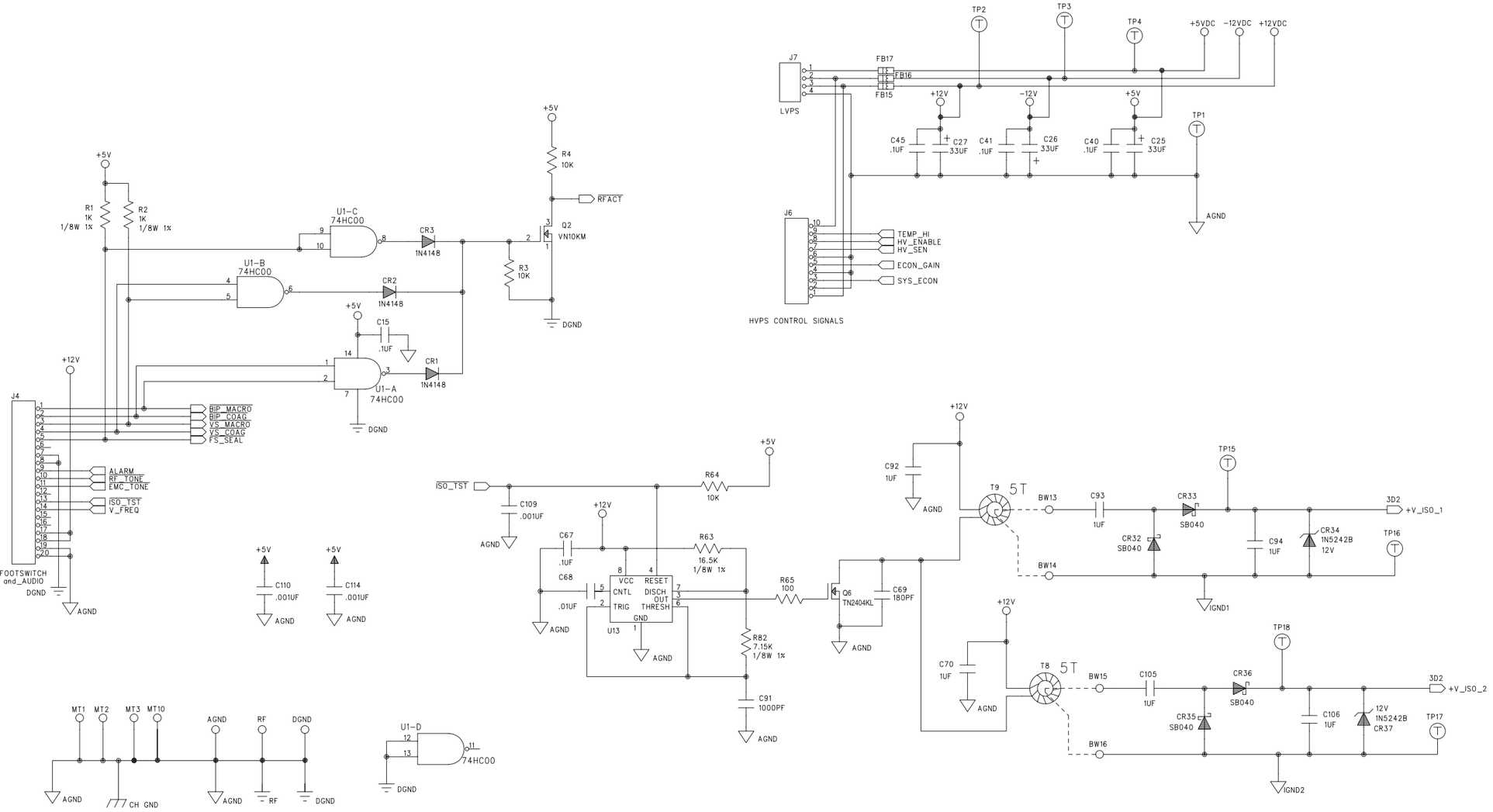
This supplement contains the schematics for the following printed circuit boards:

- Display board
- RF board
- Footswitch board
- High Voltage Power Supply board
- PCB Controller board
- Smart Connector

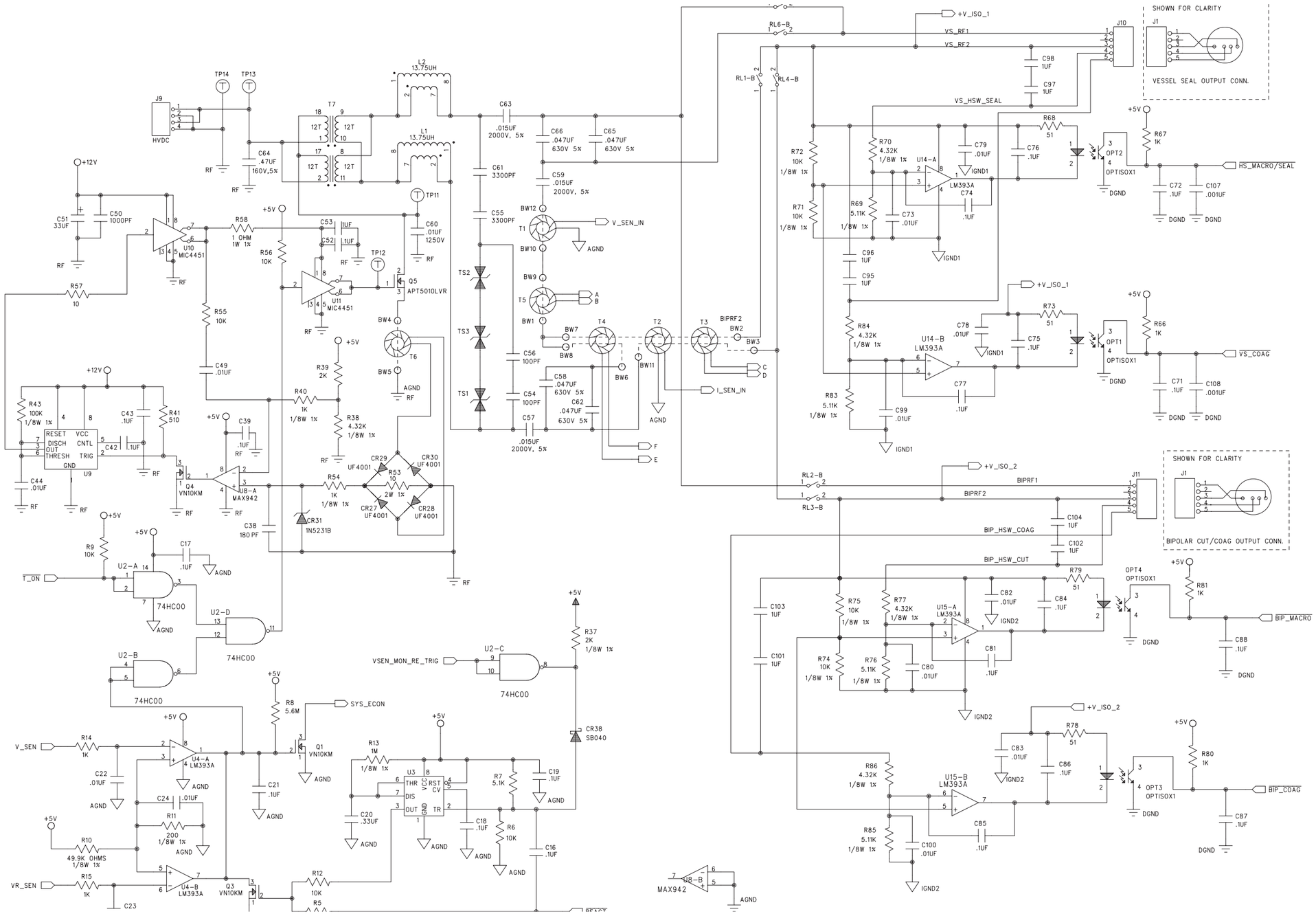
Display Board



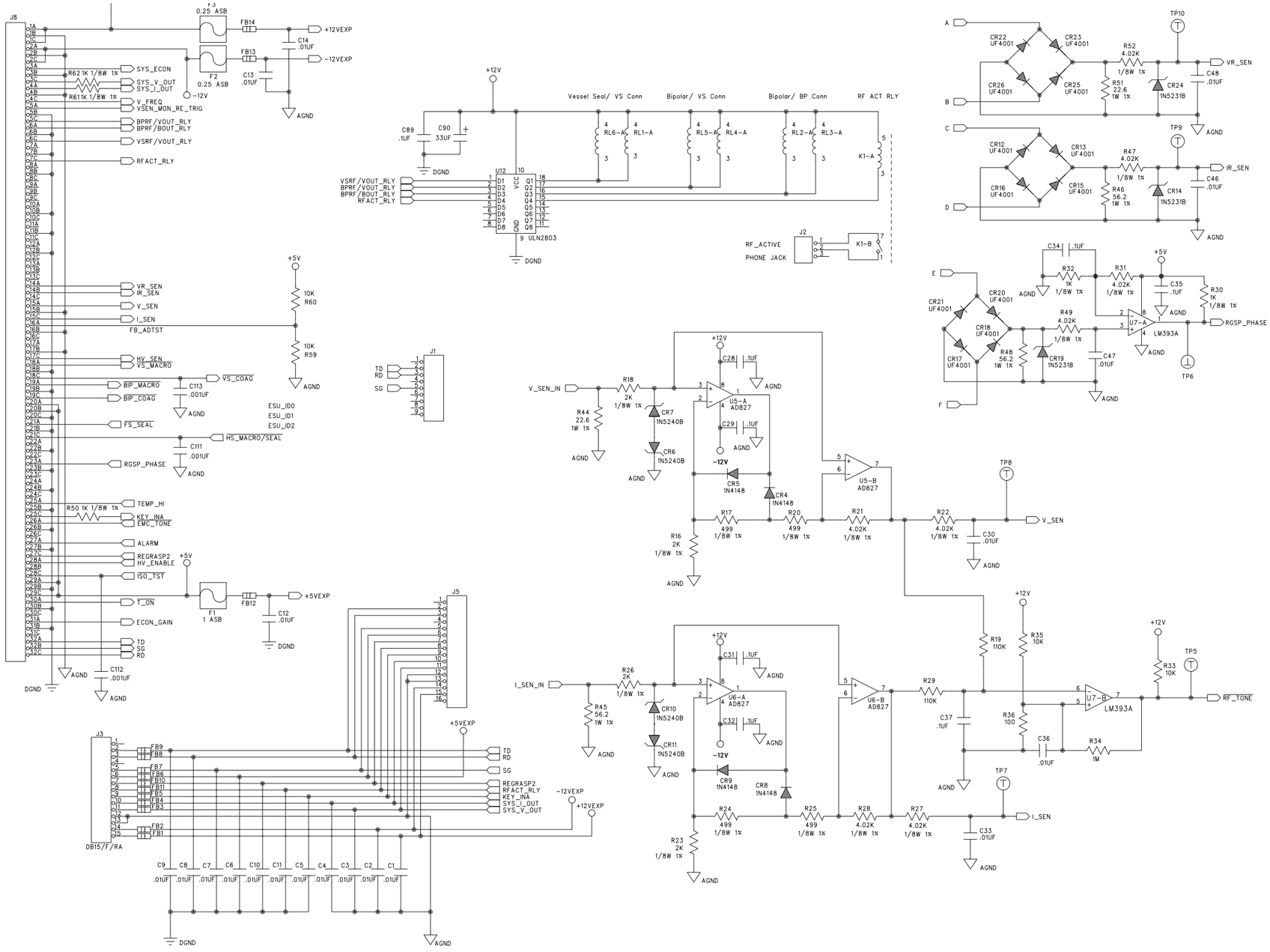
RF Board - sheet 1 of 3



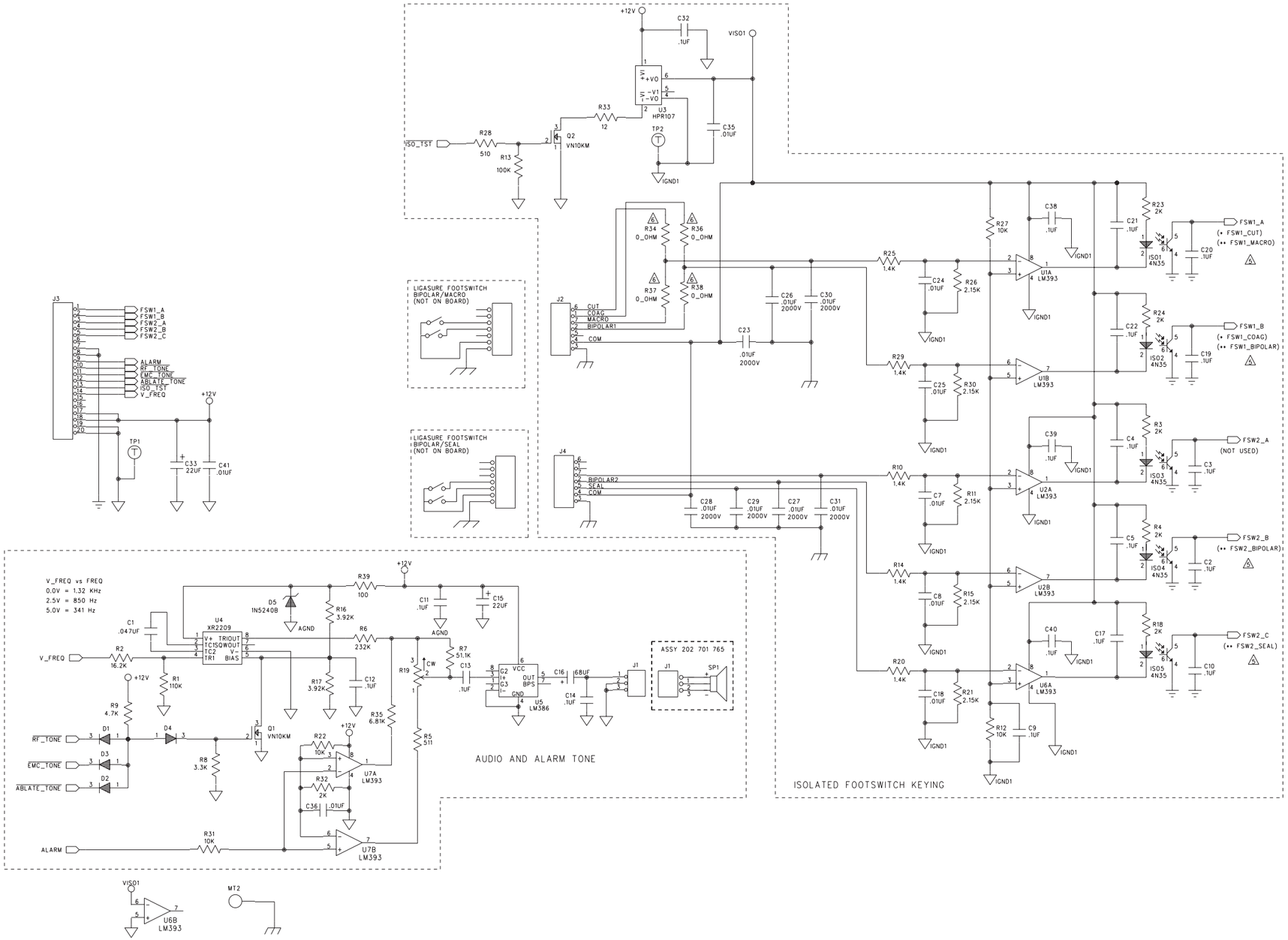
RF Board - sheet 2 of 3



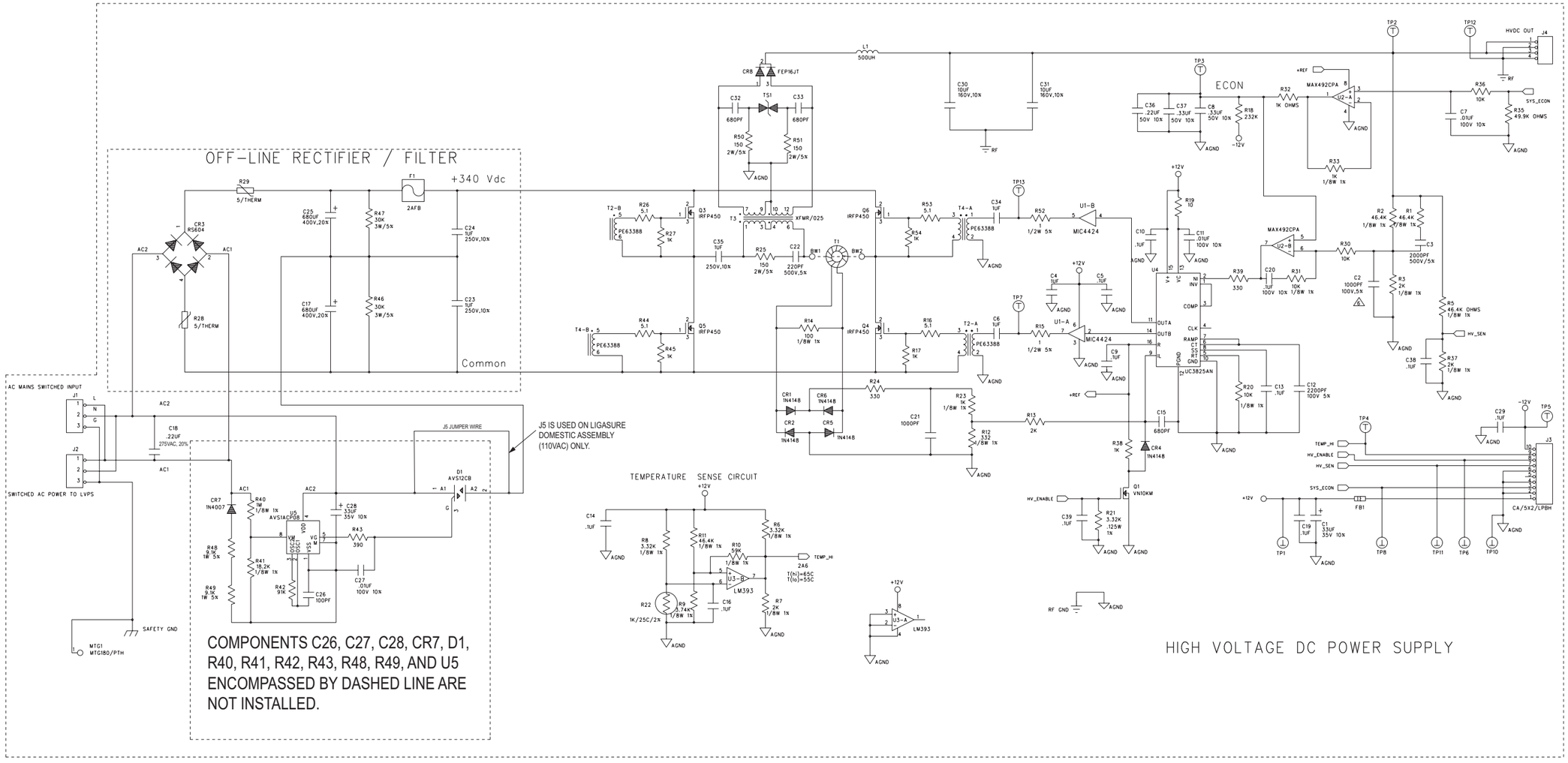
RF Board - sheet 3 of 3



Footswitch Board

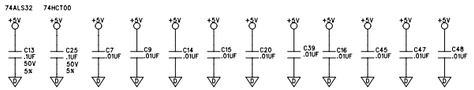


High Voltage Power Supply Board



PCB Controller - sheet 1 of 2

BYPASS CAPS :



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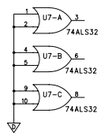
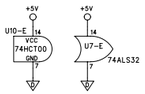
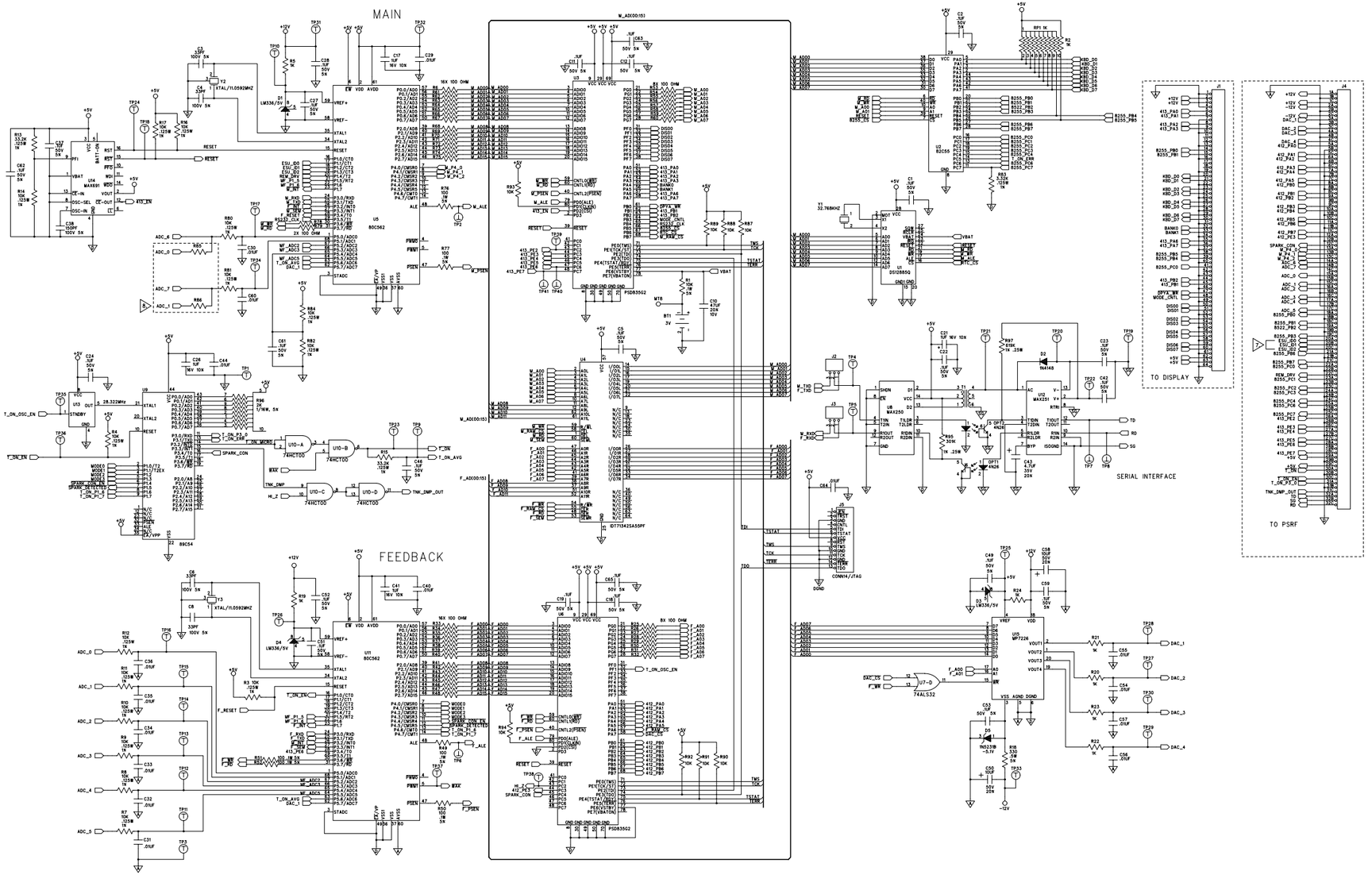




SIGNAL CROSS-REFERENCE CHART

SIGNAL \ PRODUCT	LIGASURE
M_P4_0 (U5)	REMPOT_INC\
M_P4_1 (U5)	REMPOT_U\D
M_P4_2 (U5)	REMPOT_CS\
413_PA0 (U3)	MACRO_LMP
413_PA1 (U3)	COAG_LMP
413_PA2 (U3)	VS_LMP
413_PA3 (U3)	REGRASP
413_PA5 (U3)	SMT_CNT1
413_PA6 (U3)	SMT_CNT2
413_PA7 (U3)	UNUSED2
413_PB1 (U3)	_DPYB_WR
413_PB2 (U3)	_DPYC_WR
413_PE2 (U3)	_EMC_TONE
413_PE3 (U3)	UNUSED1
413_PE4 (U3)	ALARM
413_PE5 (U3)	REGRASP0
413_PE6 (U3 & U11)	HV_ENABLE
413_PE7 (U3)	ISO_TST
412_PA0 (U6)	MON_RLY
412_PA1 (U6)	BIP_RLY
412_PA2 (U6)	MONO2_RLY
412_PA3 (U6)	MONO1_RLY
412_PA4 (U6)	CUT_RLY
412_PA5 (U6)	EKG_RLY
412_PB0 (U6)	V_RLY_0
412_PB1 (U6)	V_RLY_1
412_PB2 (U6)	V_RLY_2
412_PB3 (U6)	V_RLY_3
412_PB4 (U6)	I_RLY_0
412_PB5 (U6)	I_RLY_1
412_PB6 (U6)	I_RLY_2
412_PB7 (U6)	I_RLY_3
412_PE3 (U6)	CAP_RLY

PCB Controller - sheet 2 of 2



Smart Connector